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THESIS

AN EMPIRICAL APPROACH TO LOGICAL CLUSTERING OF SOFTWARE FAILURE REGIONS

by

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March, 1994

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The approach was to use chi-square statistics on data taken from (Shimeall, 1991) to test the hypotheses, 247 faults were analyzed and the resultant clustering was cross-examined across the perspectives.

The results show that the studied failure regions have a strong tendency to form taxonomical clusters. They also exhibit a mild tendency to form functional clusters. Taxonomical clustering does not correlate with structural clustering, while functional clustering correlates well with it.

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An Empirical Approach to Logical clustering
of
Software failure regions

by

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TABLE OF CONTENTS

LIST OF FIGURES

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I. INTRODUCTION

A. MOTIVATION FOR THIS THESIS

As computing systems perform more and more sophisticated functions, the software components of such systems necessarily become larger and more complex. In addition, a plethora of critical systems, such as nuclear power plants and aircraft control systems are controlled by software. The growth in size and complexity of software results in an even faster growth in the complexity of software testing. Testing is currently a very labor intensive and expensive process that accounts for approximately 50% of software system development (Myers 1979, Korel 1990).

The need for reliable software operation is increasing rapidly. This implies that extensive software testing is frequently necessary despite expenses. This thesis deals with software testing, and is intended as a sequel to previous research on failure region identification (Shimeall et al 1991) and failure region clustering (Ginn, 1991).

B. OUTLINE OF THE PROBLEM

Failure regions appear to have a tendency to ***cluster*** so the neighborhood of a specific failure region may reveal more software faults than the one that caused the region. An empirical study (Ginn 1991) on data obtained by Shimeall and Leveson (1991) has demonstrated this ***clustering tendency*** of failure regions using appropriate clustering criteria for multidimensional nominal types of data (Jain and Dubes, 1988). A number of issues have been raised from this research:

- Several failure regions demonstrated a strong clustering tendency in one dimension but weak clustering in other dimensions. However it is not known if this is a coincidence or normal behavior of failure regions.

- Software faults were numbered in order as they were discovered, by the various testing techniques applied by Shimeall and Leveson (1991), so that many of the sequentially numbered faults were discovered by the same detection technique. There was also a strong tendency of clustering for sequential faults, but it is as yet unknown if there is a correlation between certain detection techniques and certain types of fault clusters.

- It is not clear which types of conditions and variables are more likely to result in clusters.

There is empirical evidence that known failure regions may be used to understand the relationship of one fault to another. Failure regions offer a mechanism for identifying common features among faults, because the relationship between two failure regions corresponds to the relationship of the code locations of the associated faults. The goal of this research will be an improved testing technique that incorporates failure region behavior. To do this, we need to better understand how parts of the program interact, since faults with similarities in their failure regions are expected to occur under similar conditions.

C. OVERVIEW OF THE THESIS

Chapter II gives an extensive review of preceding research on software testing in general and failure region analysis in particular. Chapter III introduces a testing technique on clustering and presents empirical results from the application of the said technique on the results of a software experiment. Finally, Chapter IV summarizes the conclusions that can be drawn from the results and offers suggestions and recommendations for further research.

II. BACKGROUND AND RELATED WORK

This chapter reviews software testing definitions and methods for dealing with software fault and failure association. Symbols and terminology are similar to those used in the classical papers (such as Weyuker and Ostrand, 1980, Goodenough and Gerhart, 1975). A brief overview of theories of software testing related to our research is presented. Previous work, both empirical and theoretical, in the area of failure regions analysis is included. Finally the cluster analysis technique that has been used by Ginn (1991) is briefly presented.

A. SOFTWARE TESTING

1. Basic Definitions

Testing is a method of program verification that deduces from execution that a program possesses required properties (Morell 1990).

The input data for the majority of programs come from a multi-dimensional space. An example given by Amman and Knight (1988) refers to a program processing an input of 20 floating point numbers thus having 20 dimensions.

We shall use **D** for the input domain of a program **F**, and **R** for the output range of **F**. On input **d** ($d \in D$) **F**, if it terminates, produces output **F(d)** ($\in R$). Hence the program, may be viewed as a mapping from the input domain to the output range.

The output specification for **F** is given by **OUT(x,y)**, where $x \in D$ and $y \in R$. **F** is correct on input **d** (abbreviated **OK(d)**) if **F(d)** exists and **OUT(d,F(d))**. A test **T** ($\subseteq D$) is formally defined as a subset of the input domain (after Weyuker and Ostrand, 1980, Goodenough and Gerhart, 1975). More often than not, software failures appear at what seems to be an obscure set of data or a special case (Ammann and Knight 1988). This introduces an additional complication to the testing process.

2. Ideal, Valid, and Reliable Tests

An ***ideal*** test must be ***valid***, which implies that for every fault in program **F** exist entries in test **T** that cause the fault to execute and produce incorrect output (Goodenough and Gerhart 1975). Formally:

$$Ideal(T) \leftarrow (\forall Fault \in F: \exists\, d \in T \wedge \neg OK(d)) \qquad \textbf{(2.1)}$$

A ***reliable*** test is one that either produces entirely correct output or entirely incorrect. Formally:

$$\mathit{Reliable}(T) \leftarrow [(\forall d \in T\colon OK(d)) \vee (\forall d \in T\colon \neg OK(d))] \qquad (2.2)$$

The importance of a failure region clustering theory becomes apparent here from the point of view of test selection. It was shown by Weyuker and Ostrand, (1980) that an ideal and reliable test is exhaustive therefore it is desirable, for the sake of feasibility, to select a much smaller test to the end of revealing certain types of faults. A failure region clustering theory provides same guidelines for this type of selection.

B. PROGRAM PATHS

1. The Concept of a Program Path

A ***path*** in a program is defined as a sequence of statements (Richardson and Clarke 1985). It is quite obvious that a path may be decomposed into a number of subsidiary paths. A block statement is decomposed into its constituent enclosed statements whose execution depends upon evaluation of a condition which is also part of the block statement.

The control flow statements in a computer program partition the input space into a set of mutually exclusive domains each of which causes a corresponding path to be executed (White and Perera 1986). This concept of path offers a natural way to partition the input domain.

The subdomain D_j of path j, is defined by a boolean expression (say $P(j)$) that is the conjunction of the path's branch predicate constraints. In general these predicates are expressed in terms of both local (program) and input variables. However it is possible to replace each program variable appearing in the predicates by its symbolic value defined in terms of input variables along that path and get an equivalent constraint that is the partition boundary, P(j), as a function of input variables only (also predicate interpretation after White and Wiszienwski 1988).

2. Programs as Sets of Partial Functions

Using the concept of path, as defined in the previous subsection, we can model a program as a set of partial functions from the input partitions (D_j) to the output space (O), each of the partial functions corresponding to the execution of a sequence of statements along the corresponding path (j) (Richardson and Clarke 1985). Formally:

$$S_{j,1}S_{j,2}..S_{j,n}(D_j) = O' \subseteq O \tag{2.3}$$

where $S_{j,1}S_{j,2}..S_{j,n}$ stands for the sequence of statements[1] along path j. In the case of loops executing along the path (let $S_{j,l}S_{j,l+1}..S_{j,l+m}$ be the sub sequence

---

[1] The condition evaluations are included into the sequence of statements for consistency although, since the path is pre-determined they do not affect the result of the operation.

of statements in the loop body) the path sequence of statements may be written $S_{j,1}S_{j,2}(S_{j,i}S_{j,i+1}..S_{j,i+m})^{+}..S_{j,n}$. This model assigns sequences that differ only by their number of loop iterations to the same program path.

As a path may be decomposed into other paths, an input domain partition may be refined by the same token in a hierarchical way, as new branch predicate conditions are "AND ed" to the existing. This suggests a more generic approach to the issue of input domain partition than the one suggested by Richardson and Clarke (1985) where they distinguish this partition into ***implementation*** and ***specification*** partitions and point out certain discrepancies due to the inherent differences of the specification versus the implementation languages.

3. Regular Expressions for Paths

The set of paths, on a flow-chart, can be expressed in algebraic form (Beizer 1990). Path expressions are converted to ***regular expressions*** that can be used to examine structural properties of program paths.

For any single path, j, of the program, the sequence of statements $S_{j,1}S_{j,2}..S_{j,n}$ introduced in the previous section is the ***path product*** of j. Path products are also defined on ***path segments***. The path that consists of successive path segments, has a path product equal to the concatenation of

their path products. A set of parallel paths between two nodes has a path product equal to the sum of the path products of the parallel paths.

Condition evaluations are retained in the path products for consistency (cf. previous subsection). In fact, the path products of the two segments starting from a decision point (such as an **if** C **then else** construct or a loop exit condition etc) are preceded with the condition C and condition ¬C respectively, depending upon which part of the decision (if or else) results in their execution. The regular expressions for paths provide a concise and compact notation for both the ***path conditions*** (which, for a given set of paths, are derived by conjunction of all conditions on successive path segments and disjunction of conditions on parallel path segments) and ***path actions*** (which, in the previous section, are modelled as partial functions from the input domain to the output range).

C. ON ERRORS AND FAULTS

A ***fault*** is an erroneous piece of program source code, while an ***error*** is a discrepancy between a computed value and the true, specified, or theoretically correct value.

A ***failure*** specifies the inability of a module to perform its specified function and includes both erroneous output and failure to produce output (see ANSI-IEEE STD 610.12-1990).

A fault (E) is formally modeled as a 3-tuple (Shimeall et al 1991):

$$E = \langle L_r, V_r, C_r \rangle \tag{2.4}$$

where L_r is the location of the fault[2] (which is some program statement), V_r the list of variables that form the error caused by the fault and C_r is a Boolean condition under which the fault is activated. An interesting point is that a fault activation does not always imply a failure (coincidental correctness, Morel 1988). There are three conditions that must hold true for a fault to produce a failure (Shimeall et al 1991) which, apart from C_r, are the ***reachability*** condition and the ***error propagation*** condition.

A basic assumption about the faults in code is the competent programmer hypothesis (DeMillo et al 1978). This states that a competent programmer will write a program that is syntactically close to the correct program.

A taxonomy of the types of faults possibly found in a program is given by Beiser (1990):

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[2] Sometimes a fault is "distributed" to more than one locations while certain types of faults, such as missing functions etc., do not have a well defined location.

1. Requirements and Specifications

These include incomplete or self-contradictory specifications, missing, wrong or superfluous features, and not-well-specified feature interactions.

2. Structural Errors

Such as control and sequence errors, logic errors, incorrect formulae applications, use of uninitialized variables. These can be further divided (Richardson and Clarke 1985) into:

a. Computation Errors

A computation error occurs when the correct path through the program is taken, but the output is incorrect because of faults in the computation along the path.

b. Domain Errors

A domain error (White and Perera 1986) occurs when a specific input follows the wrong path due to an error in the control flow of the program. They are of two kinds:

(1) ***Missing Path Errors***: They occur when a special case requires a unique sequence of actions, but the program does not contain a corresponding path.

(2) ***Path Selection Errors***: They occur when the program recognizes the need for a path, but incorrectly determines the conditions under which the path is executed.

3. Data Errors

Occur when a specific input follows the correct path, but an error such as wrong data declarations, wrong data initialization (especially in shared dynamic objects), etc. results in erroneous output.

4. Coding Errors

The most common coding errors are documentation inconsistencies, typographical errors, and erroneous use of a program statement when its side effects are not well understood.

5. Interface Errors

Such as interface communication problems, incorrect input-output format, wrong subroutine control sequence, wrong call parameters, inconsistent entry or exit parameter values, etc.

D. ON FAILURE REGIONS

A software ***failure region*** ($G \subseteq D$) is the set of all input values that are mapped by an individual program fault onto any failure (or onto a failure set, as in figure 1.1). It is noted that the concept of failure region includes both the input points which cause erroneous output and the geometry of it. These sets are always finite, since the number of representations in a finite machine is limited, but more often than not intractably large. The ***failure region boundaries*** are defined by Boolean conditions on the input domain.

Shimeall et al (1991) demonstrate a technique that analytically determines the three conditions for a known fault (which include all conditions for reaching, activating and propagating the fault), by ***symbolically executing*** (King 1976) the source code on every "loop [0,1]" path (Loops are handled as in previous section, by applying either the exit condition or the loop effects) and conjuncting the obtained Boolean expressions. The conjunction of those conditions is the mathematical specification of the failure region boundary (which may be called **Bound(G)**) subject to the limitations of finite representation in computing machines.

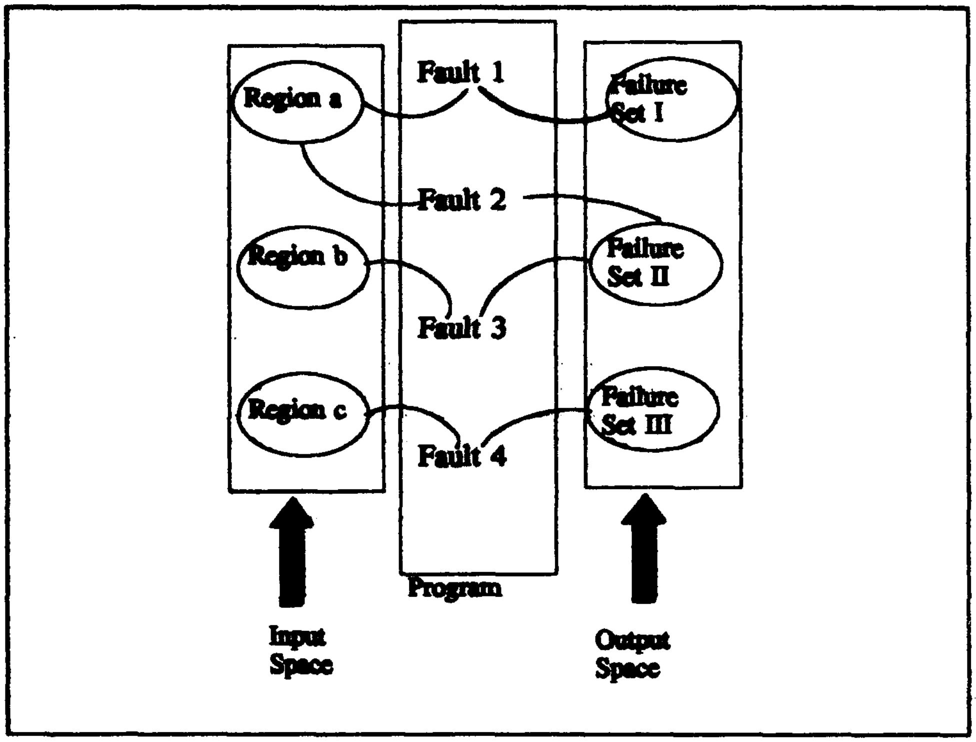

Figure 1.1 Associations between Failure regions Faults and Failures (adapted from Shimeall et al 1991)

E. BOUNDS CORRELATION BETWEEN DIFFERENT FAILURE REGIONS

The dimensions of the input domain of a program can provide a set of criteria for the correlation between different failure regions. To this end a classification of these dimensions is used (Ginn 1991), with respect to any pair of failure regions:

- The dimensions that appear in both boundaries in exactly the same way are termed ***identically participating*** dimensions.

- Those who appear in both boundaries but not in an identical way are termed ***coincidentally participating*** dimensions.

- The dimensions that do not appear in the boundaries of both regions are called ***nonbounding*** dimensions, because the boundaries these dimensions place on failure regions are no more restrictive than their entire range of values.

In Ginn (1991) the Identical and Coincidental dimensions are collectively referred to as ***Composite*** dimensions.

III. CLUSTER ANALYSIS AS A PREDICTOR FOR FAULTS

A. CLUSTER ANALYSIS

The identification of groups that have similar characteristics is the goal of clustering analysis. In the context of this thesis, the objective of failure region analysis is to investigate clustering of failure regions and identify the logical relation of the program locations of the faults responsible for these failure regions.

By definition of failure region (Shimeall et al 1991 for example) the execution of a program, with data from some failure region as input, will ***reach***, ***activate***, and ***propagate*** to the output the corresponding program fault. The conjunction of predicates that defines the bound of the region (Chapter II-D) contains a statement of the reachability, activation and propagation conditions for the corresponding fault.

The criterion used by Ginn (1991) assumed that clustering between failure regions occurs when identical or similar predicates appear in the bounds of these failure regions. Therefore, one could use identical dimensions (corresponding to identical predicates) or composite dimensions

(corresponding to both identical and similar predicates) to define a measure of clustering. The assumption made by Ginn (1991) is reasonable, because it is expected that when failure regions correspond to faults that share some program paths (therefore some of the predicates in common) it is possible, but not necessary, that the same input may reveal all of them. On the contrary, when the faults do not share any path, it is impossible for both of them to be revealed by the same input.

The criteria used for the failure region bounds variables are essentially ordinal: identical, coincidental, nonbounding, in descending order. Therefore relative values cannot be assigned to them. There are, however, two different coefficients that may serve as a measure of clustering for ordinal data (see Jain and Dubes 1988):

$$S(G_i, G_j) = \frac{a_{00} + a_{11}}{a} \tag{3.1}$$

The ***simple matching*** coefficients for two failure regions G_i, G_j are defined by 3.1, where a_{00} stands for the non-bounding dimensions of both

failure regions a_{11} for the shared[3] dimensions of Gi and Gj, (cf. Chapter II-E) and a for the total number of input dimensions. The similarity of failure regions G_i and G_j is greater the closer the simple matching coefficient is to unity, since $S(G_i,G_i)=1$, because $a_{01}=a_{10}=0$. The inclusion of a_{00} in the numerator of the coefficient emphasizes equally bounding and non-bounding dimensions and can result in very high (close to unity) values of the coefficient when the total number of input dimensions is much greater than the bounding dimensions of two failure regions. Suppose for example the pair of failure regions:

$$Bound(G_1) = (x<5) \wedge (y<8) \wedge (z<10) \tag{3.2}$$

$$Bound(G_2) = (w<0) \wedge (u<0) \tag{3.3}$$

If the total number of dimensions is 250 then $a_{00}=245$, $a_{11}=0$, and $S(G_1,G_2)=245/250=0.98$, which implies a high degree of clustering while it is obvious that the failure regions are not related.

---

[3] The term shared may refer to dimensions appearing in identical predicates in two failure regions definitions, or may include both similar and identical predicates. Ginn (1991) investigates both cases separately.

The ***Jaccard*** coefficients, defined by 3.4, seem more sensitive to clustering since they emphasize more the composite dimensions, as opposed to the simple matching coefficients that are symmetric in composite an non-coincidental dimensions. As with the simple matching coefficients, the similarity of failure regions G_i and G_j is greater the closer the Jacard coefficient is to unity, since $J(G_i,G_i)=1$.

$$J(G_i,G_j) = \frac{a_{11}}{a-a_{00}} \tag{3.4}$$

However, under certain circumstances, the reliability of Jaccard coefficients is debatable. Suppose fcr example the pair of failure regions defined by (3.5), (3.6):

$$Bound(G_1) = (x<5) \wedge (y<8) \wedge (z<10) \tag{3.5}$$

$$Bound(G_2) = (x<5) \wedge (y<8) \wedge (z<10) \wedge (w<0) \wedge (u<0) \tag{3.6}$$

In this case the Jacard coefficient $J(G_1,G_2)=3/(3+2+0)=0.6$, while it is intuitively obvious that the relation is probably stronger than is suggested by the coefficient. On the other hand, the simple matching coefficient, depending upon the number of dimensions that are non-bounding for both G_1 and G_2 may vary between 0.6 and 0.9999.

In the following sections, we shall examine how pairs of faults may result in clustered failure regions, as well as how the Jaccard coefficients are affected.

B. RELATED FAULTS

The goal in analyzing fault relations is to understand the clustered failure regions, which appear in software experiments (Ginn 1991). To this end, it is required to determine what kind of fault relationship results in clustered failure regions.

1. Logical Relation of Faults

Faults can be ***logically related*** if they are either the same logical flaw (***Taxonomically related***) or they are located in regions of programs that compute the same part of the application (***Functionally Related***).

2. Taxonomically Related Faults

A logical flaw is an error, or misunderstanding by the programmer, in the design logic of a program that results in a number of faults. Taxonomically related faults are expected to be both application dependent and programmer dependent. They are application dependent because it is expected that applications requiring a great number of a certain type of constructs (say loops or if statements for example) are more prone to the type of faults peculiar to these constructs (loop iteration and control flow faults respectively for this example). It is not always clear from the specification of a program exactly how many such constructs will be required, and it is usually up to the programmer to decide for the implementation details. However, the higher level design of a program always gives an indication whether the implementation requires many iterations or a lot of case handling etc. Therefore this type of faults depends both on the design and the implementation details.

On the other hand they are programmer dependent because every programmer has his/her own weak and strong points in developing a software design, and it is obvious that some phases of his/her work will be

more prone to faults than others. This also holds true for both the design and the implementation phases.

3. Taxonomical Fault Classification of a Software Experiment

The classification of the known program faults in a set of eight redundant versions of a combat simulation program (Shimeall 1991a, 1991b) constructed as part of a software experiment (Shimeall and Leveson 1991) were analyzed. The fault categories used in this taxonomy are from Beiser (1990). According to his classification scheme each fault is characterized by the type of logical flaw that produced it (for example case selection bug, control logic bug etc) and is assigned a four digit code number.

The first digit is characteristic of the highest level of the taxonomy hierarchy (i.e., Structural Bug, has code 3xxx) while the last digit specifies the exact category of the fault (for example a Structural, control state fault, has code 3154). The advantages of this taxonomy is that provides an easy hierarchical and logical scheme, and the four digits of the code specify the four levels of the used hierarchy (cf. Chapter II section C for a discussion of the highest levels).

The results of the fault classification in the eight versions are presented in Table 3.1 (detailed results including fault relative frequency

histograms for the eight versions, and for the observed to expected relative frequency ratio of the total number of faults are presented in Appendix B, Figures B.1 to B.8). In addition to the fault statistics, in the table we include the number of statements, if and case selection statements, and loop constructs.

4. The "Taxonomical Clustering" Hypothesis

The testing of the ***"taxonomical clustering"*** hypothesis is performed by comparison of the actual results with a simple random model that assumes that, given the total number of faults in a program, the probability of an fault occurrence in any line is equal to the ratio of the total number of faults by the total number of lines. The, ratio, is the expected fault rate for the given program. The expected number of faults for each of the categories in Table 3.1, for the random fault distribution, is calculated as the product of the fault rate time the number of statements where this type of fault can occur.

Within the scope of our working model, processing, initialization and algorithmic faults (codes 321x, 322x, 323x) occur in all program statements apart from if, case and loop constructs. Loop and iteration faults (code 314x) occur in loop constructs. Control logic, case selection and

control state faults (code 312x, 313x, 315x) may appear in if or case statements. The exception handling faults appear usually either in control (if, case) statements or loop exit conditions. Therefore we assume further that, on the average, half of the faults in loop and control statements are on exception handling and the other half on loop, iteration and control respectively.

The random fault allocation that results from the use of our model, is also included in Table 3.1 for the eight program versions. In this case the "random" version number has the subscript r.

In Appendix B we present the relative frequency distribution for both the actual number of faults and the model predictions. To test the goodness of fit of the observations to the random fault distribution model we make use of the ***Chi-Square (χ^2) One-Sample-Test*** (Siegel and Castellan 1988). This test gives the ***level of significance*** (probability of occurrence in fact) that the χ^2 statistic, which increases with the difference between the observed and the expected fault distribution, is greater than a certain value. The higher the probability of the said difference the more confident we are that the selected model corresponds to the actual distribution. However, the results of Table 3.1 imply that the probability of the observed differences

between the actual number of faults and the model prediction is below 0.001, because for 3 degrees of freedom (since there are four fault categories) the smallest value of χ^2 was 19.7 in version VI. Therefore we can conclude that the fault distribution is not uniform. This implies that the faults that have the most opportunity of being committed are not always the most frequent in a program.

It is evident from the statistics in Table 3.1 that control logic, case selection and control state faults appear at a rate about fourteen times the average fault ratio in the program while processing and initialization fault rate is about 30% of the average. This leads to the conclusion that the handling of the control logic of the program, at least in the CONFLICT experiment (Shimeall 1991a, 1991b, Shimeall and Leveson 1991) and for the programmers selected, represents a task of much greater difficulty than processing and initialization in the same program.

TABLE 3.1
(PROGRAM STATISTICS, FOR TAXONOMICAL CLUSTERING)

Version	if + case statements	loop constructs	other statements	314x (loop and iteration)	312x, 313x, 315x, (control-logic, case selection, control state)	321x,322x 323x,(processing and initialization)	Fault in exception handling (316x)	Total
I	250	184	1980	0	9	15	2	26
I_r	250	184	1980	1	1.3	21.3	2.3	26
χ^2	-	-	-	1	45.6	1.86	0.04	48.5
II	123	86	1331	0	21	3	2	26
II_r	123	86	1331	0.73	1.0	22.5	1.73	26
χ^2	-	-	-	0.73	400	16.9	0.04	417.7
III	108	88	1005	1	27	8	3	40
III_r	108	88	1005	1.43	1.76	32.2	3.2	39
χ^2	-	-	-	0.13	362.0	18.2	0.01	380.3
IV	206	119	1678	1	8	7	3	23
IV_r	206	119	1678	0.6	1	16	1.6	19
χ^2	-	-	-	0.27	49.0	5.1	1.2	55.6

TABLE 3.1
(PROGRAM STATISTICS, FOR TAXONOMICAL CLUSTERING)

Version	if + case statements	loop constructs	other statements	314x (loop and iteration)	312x, 313x, 315x, (control-logic, case selection, control state)	321x, 322x 323x, (processing and initialization)	Fault in exception handling (316x)	Total
V	153	93	1298	0	28	6	1	40
V_r	153	93	1298	1	1.7	29	2.7	35
χ^2	-	-	-	1	406.9	18.2	1.1	427.2
VI	200	101	1905	1	5	13	3	22
VI_r	200	101	1905	0.55	1.1	19.02	1.32	22
χ^2	-	-	-	0.37	13.8	3.36	2.14	18.2
VII	201	133	1644	1	18	8	3	31
VII_r	201	133	1644	1	1.5	25	2.5	30
χ^2	-	-	-	0	181.5	11.6	0.1	193.2
VIII	95	78	1158	1	31	1	8	41
$VIII_r$	95	78	1158	1.2	1.5	36.5	2.7	41
χ^2	-	-	-	0.04	580.2	34.5	10.4	639
TOTAL	1336	882	11999	5	148	61	25	248
$TOTAL_R$	1336	882	11999	7.51	10.8	209.4	18.2	239
χ^2	-	-	-	0.8	1741.0	105.4	2.6	1843

5. Taxonomical Clustering of Failure Regions Compared to the Structural Clustering of Failure Regions

In this section, we examine whether the logical clustering of failure regions correlates with the number of shared dimensions in their bounds. The number of shared dimensions at the bounds of two failure regions has been used in the definition of a clustering metric, the Jaccard coefficient between two regions, by Ginn (1991). On the other hand, we consider two failure regions as members of the same Taxonomical cluster if the associated faults are both results of similar logical flaws. We classify the Taxonomical clusters as follows:

- ***Type A***: Corresponds to loop and iteration faults (code 314x).
- ***Type B***: Corresponds to control logic, case selection and control state (codes 312x, 313x, 315x) faults.
- ***Type C***: Corresponds to processing, initialization and algorithmic faults (codes 321x, 322x, 323x).
- ***Type D***: Corresponds to faults in exception handling (code 316x).

Summary statistics of this comparison are presented in Table 3.2 (Details are included in Appendix D). From these results it is apparent that the appearance of shared dimensions, and the variation of the Jaccard

coefficient, on failure region bounds does not depend on the taxonomical clustering as analyzed in subsection b, where the clustering criterion between different failure regions has been whether they correspond to faults resulting from the same logical flaw.

TABLE 3.2
AVERAGE AND STANDARD DEVIATION OF THE JACCARD COEFFICIENT BETWEEN TAXONOMICALLY CORRELATED FAILURE REGIONS

VER-SION	Failure region pair of type A	Failure region pair of type B	Failure region pair of type C	Failure region pair of type D	Uncorrelated failure region pair
I	-	0.051±0.115	0.049±0.134	0.25[4]	0.042±0.108
II	-	0.050±0.149	0.133	-	0.029±0.066
III	-	0.076±0.135	0.054±0.107	0	0.055±0.115
IV	-	0.032±0.061	0.050±0.118	0.077	0.036±0.092
V	-	0.019±0.085	0.017±0.034	-	0.008±0.035
VI	-	0.073±0.230	0.059±0.118	-	0.018±0.039
VII	-	0.074±0.174	0.031±0.075	0.111±0.19	0.018±0.065
VIII	-	0.123±0.429	-	0.134±0.181	0.117±0.227

In Table 3.3 we present the same statistics as in Table 3.2 with the difference that, in this case, we use the average non-zero Jaccard coefficient between taxonomically correlated failure region. This indicates

[4] In entries without Standard Deviation there is only one value.

whether the taxonomical clustering of failure regions correlates with the number of shared dimensions in their bounds, when these shared dimensions exist.

TABLE 3.3
AVERAGE AND STANDARD DEVIATION OF THE NON ZERO JACCARD COEFFICIENT BETWEEN TAXONOMICALLY CORRELATED FAILURE REGIONS

VER-SION	Failure region pair of type A	Failure region pair of type B	Failure region pair of type C	Failure region pair of type D	Uncorrelated failure region pair
I	-	0.124±0.150	0.247±0.361	0.250	0.164±0.159
II	-	0.393±0.196	0.133	-	0.128±0.09
III	-	0.171±0.139	0.139±0.134	-	0.159±0.143
IV	-	0.129±0.048	0.156±0.167	0.077	0.131±0.136
V	-	0.315±0.172	0.067	-	0.115±0.089
VI	-	0.73	0.191±0.147	-	0.086±0.026
VII	-	0.434±0.147	0.133±0.109	0.333	0.173±0.110
VIII	-	0.469±0.222	-	0.283±0.117	0.387±0.258

The results in Table 3.3 provide us with evidence in favor of the intuitively obvious hypothesis that the structural clustering of failure regions does not depend on the taxonomical clustering. This result can be attributed to the fact that structural clustering of failure regions, depends strongly on

the control and data flow structure of the program, with respect to the corresponding fault location. On the other hand the taxonomical clustering dependence is restricted to the type of statement at the fault location.

6. The Case of Functionally Related Faults

The hypothesis, that logically-related faults located in regions of programs that compute the same part of the application may lead to some type of clustering, is based on the intuitively obvious assumption that some parts of a problem may be more difficult to handle or more "error prone" than others (Brilliant et al 1990). We shall call this type of faults ***functionally related***.

7. Functional Fault Classification of a Software Experiment

The distribution of the known program faults in the eight versions of the combat simulation program (Shimeall 1991, 1991b) to the program modules implementing different functional requirements of the specification was analyzed. We classified the functional clusters, according to the CONFLICT Specification (Shimeall 1991b) as follows:

- ***Type I***: Positioning and Movement

- ***Type II***: Observation
- ***Type III***: Attrition
- ***Type IV***: Communication
- ***Type V***: Environment
- ***Type VI***: Restoration
- ***Type O***: Others (Includes the main procedure of CONFLICT and some procedures for initialization and output format)

8. The Functional Clustering Hypothesis

The null hypothesis that fault distribution is uniform over the program locations was used in this analysis to test the clustering hypothesis. The number of expected faults for each functional requirement of the specification was set equal to the total number of lines of routines implementing the requirement times the fault rate (as in subsection 1b) for the program.

The results of this analysis are presented in Table 3.4., while detailed analysis is included in Appendix D.

To test the goodness of fit of the observations to the random fault distribution model we make use of the ***Chi-Square (χ^2) One-Sample-Test***

(Siegel and Castellan 1988), as in subsection 4. In this case there are seven categories of faults, therefore the degrees of freedom are six.

Apart from versions IV, VII and VIII, the confidence level for the null hypothesis is varying from 1% to 31%. In versions IV, VII and VIII this confidence drops below 0.1%. This result, however, may be attributed to the low (less than five) expected number of type I, II, III, V, VI and O faults for version IV and the low expected number of type I, V, VI faults for version VIII. In version VII the result may be attributed to the low, 3.1, number of expected fault at column IV compared to the 10.5 observed.

The above discussion can be verified in case we consider only two fault categories for version IV, Type IV with 7 observed and 6.7 expected faults, and all others with 16 observed and 16.3 expected faults. This will result in a χ^2 equal to 0.019 and a corresponding confidence level, one degree of freedom this time, greater than 90%.

In the case of version VIII, we may consider the fault categories II, III, IV, O and all others, with four degrees of freedom, and the χ^2 will be equal to 14.85, which gives a confidence level of 1%.

The confidence level increases accordingly with all the remaining versions if we group together all categories with expectation value less than

5 as suggested by Siegel and Castellan (1988). Under the circumstances, we cannot either accept or reject the null hypothesis of uniform distribution of faults.

An alternate hypothesis, that the faults are uniformly distributed between type IV (Communication), type III+II (Attrition and Observation) and all other types is tested in Table 3.5. The alternate hypothesis assumes that some type of functional clustering exists, because 2/3 of the faults are clustered in the Communication, Attrition and Observation modules, which, on the average, constitute the 50% of the total lines of code.

TABLE 3.4
(PROGRAM STATISTICS, FOR FUNCTIONAL CLUSTERING)

Version	Type I	Type II	Type III	Type IV	Type V	Type VI	Type O	TOTAL	Confidence Level
I	1	3	4	3	4	3	8	26	-
I_r	1.77	2.65	3.92	7.49	1.58	2.38	6.2	26	-
χ^2	0.33	0.05	0.002	2.7	3.71	0.16	0.52	7.5	**28.4%**
II	3	5	0	14	3	1	0	26	-
II_r	4.10	3.83	4.85	6.23	2.38	1.5	3.11	26	-
χ^2	0.295	0.008	4.85	9.7	0.16	0.17	3.11	18.3	**1%**

TABLE 3.4 (PROGRAM STATISTICS, FOR FUNCTIONAL CLUSTERING)

Version	Type I	Type II	Type III	Type IV	Type V	Type VI	Type O	TOTAL	Confidence Level
III	2	3	7	13.5	5	2	7.5	40	-
III_r	3.13	4.9	4.37	13.57	2.83	0.8	10.4	40	-
χ^2	0.41	0.74	1.6	0.00	1.66	1.8	0.81	7.0	31%
IV	0	11.5	2.5	7	1	1	0	23	-
IV_r	2.4	3.07	3.7	6.7	1.7	2.3	3.1	23	-
χ^2	2.4	23.15	0.39	0.013	0.29	0.04	3.1	29.4	<0.1%
V	0	6	2	15.5	1.5	2	13	40	-
V_r	2.6	7.9	7.3	9.0	2.3	1.5	9.4	40	-
χ^2	2.6	0.60	3.85	4.69	0.28	0.17	1.38	13.5	5%
VI	0	3	5	7.5	0	0	4.5	20	-
VI_r	0.87	2.9	1.8	8.1	1.6	1.03	3.7	20	-
χ^2	0.87	0.00	5.7	0.04	1.6	1.03	0.17	9.4	25%
VII	0	7	5	10.5	2	2	4.5	31	-
VII_r	5.0	4.6	3.8	3.1	2.4	2.0	10.4	31	-
χ^2	5.0	1.25	0.38	17.7	0.07	0	3.35	27.8	<0.1%
VIII	4	11	3	15	7	1	0	41	-
$VIII_r$	4.2	5.9	6.4	10.8	3.3	2.7	7.8	41	-
χ^2	0.009	4.41	1.8	1.63	4.15	1.1	7.8	21.0	0.1%
TOTAL	10	49.5	28.5	86	23.5	12	37.5	247	-
$TOTAL_R$	24.1	35.6	36.1	65	18.1	14.23	62.8	247	-
χ^2	22.7	5.43	1.6	6.78	1.61	0.35	10.2	48.6	<0.01%

TABLE 3.5 (ALTERNATE HYPOTHESIS TEST)

Version	Type IV	Type II+III	Type O+I+V+VI	TOTAL	Confidence Level
I	3	7	16	26	-
I_r	8.67	8.67	8.67	26	-
χ^2	3.71	0.32	6.2	10.23	0.6%
II	14	5	7	26	-
II_r	8.67	8.67	8.67	26	-
χ^2	3.28	1.55	0.32	5.15	7.6%
III	13.5	10	16.5	40	-
III_r	13.33	13.33	13.33	40	-
χ^2	[illegible].00	0.833	0.752	1.59	92%
IV	7	14	2	23	-
IV_r	7.67	7.67	7.67	23	-
χ^2	0.06	5.22	4.19	9.48	0.9%
V	15.5	8	16.5	40	-
V_r	13.33	13.33	13.33	40	-
χ^2	0.35	2.13	0.75	3.23	20%
VI	7.5	8	4.5	20	-
VI_r	6.67	6.67	6.67	20	-
χ^2	0.10	0.27	0.71	1.08	60%
VII	10.5	12	8.5	31	-
VII_r	10.33	10.33	10.33	31	-
χ^2	0.00	0.27	0.33	0.60	75%

TABLE 3.5 (ALTERNATE HYPOTHESIS TEST)

Version	Type IV	Type II+III	Type O+I+V+VI	TOTAL	Confidence Level
VIII	15	14	12	41	-
$VIII_T$	13.67	13.67	13.67	41	-
χ^2	0.13	0.01	0.20	0.34	84.3%
TOTAL	86	78	83	247	-
$TOTAL_R$	82.33	82.33	82.33	247	-
χ^2	0.16	0.23	0.01	0.40	82%

The confidence levels of the chi-square test range from 84.3% to 0.6%. Although we cannot accept or reject the alternate hypothesis, we notice that the confidence levels for acceptance are in general higher that those of the null hypothesis. The results for versions III, VI, VII and VIII are in favor of the alternate hypothesis, which implies some type of functional clustering. The results for versions II, IV, V are not in favor of the alternate hypothesis because the functional clustering tendency is stronger than the assumed by the alternate hypothesis, and only version I implies that there is not any clustering tendency favoring Attrition Communication and Observation.

Therefore it is reasonable to conclude from the data at hand that there is indeed some, not very strong, tendency of the failure regions to cluster in some groups of functional program modules more than in others.

9. Clustering of Failure Regions of Functionally Related Faults Compared to the Structural Clustering of Failure Regions

In this section, we examine whether the functional clustering of failure regions correlates with the number of shared dimensions in their bounds. In this case we consider two failure regions as members of the same functional cluster if the associated faults appear in regions of the program that compute the same part of the application. Summary statistics of this comparison are presented in Table 3.6 and 3.7 (the latter corresponds to the non zero Jaccard coefficient case) while details are included in Appendix D.

From the results of Table 3.6 it is not possible to conclude that the appearance of shared dimensions, and the variation of the Jaccard coefficient, on failure region bounds does or does not depend on the functional clustering, as defined in subsection 8, because the calculated standard deviations exceed the averages due to the abundance of zero data values.

However, from Table 3.7, we can see that the average non zero Jaccard coefficient is systematically higher for functionally correlated pairs that for uncorrelated. This implies that, given the structural clustering of two failure regions, the clustering metric is higher for functionally correlated ones. This result can be attributed to the fact that structural clustering of failure regions depends on the control and data flow structure of the program, with respect to the corresponding fault location.

It is expected that in a reasonably well structured program, faults on the same group of functional modules will share a common control and data flow path segment more often than faults on different groups.

TABLE 3.6
AVERAGE AND STANDARD DEVIATION OF THE JACCARD COEFFICIENT BETWEEN FUNCTIONALLY CORRELATED FAILURE REGIONS[6]

VERSION	Failure Region Pair of Type I	Failure Region Pair of Type II	Failure Region Pair of TypeIII	Failure Region Pair of TypeIV	Failure Region Pair of Type V	Failure Region Pair of Type VI	Failure Region Pair of Type O	Failure Region Pair Uncorrelated
I	-	0.025 ±0.04	0.140 ±0.006	0.042	0.240 ±0.49	0.125 ±0.21	0.099 ±0.19	0.0284 ±0.081
II	0±0	0.091 ±0.24	-	0.076 ±0.184	0.111 ±0.192	-	-	0.0181 ±0.073
III	0.250	0±0	0.223 ±0.312	0.097 ±0.137	0.148 ±0.091	0	0.096 ±0.14	0.046 ±0.095
IV	-	0.0374 ±0.064	0.056 ±0.096	0.0823 ±0.235	-	-	-	0.019 ±0.053
V	-	0±0	0.714	0.0227 ±0.086	0	0	0.005 ±0.03	0.0087 ±0.051
VI	-	0.336 ±0.043	0.1142 ±0.220	0.075 ±0.127	-	-	0.0643 ±0.16	0.0184 ±0.071
VII	-	0.0263 ±0.058	0.2922 ±0.239	0.131 ±0.220	0.333	0	0.117 ±0.19	0.0192 ±0.071
VIII	0.125 ±0.25	0.333 ±0.315	0.75	0.102 ±0.206	0.187 ±0.285	-	-	0.069 ±0.180

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6 In entries without Standard Deviation there is only one value.

TABLE 3.7
AVERAGE AND STANDARD DEVIATION OF THE NON ZERO JACCARD COEFFICIENT BETWEEN FUNCTIONALLY CORRELATED FAILURE REGIONS[7]

VERSION	Failure Region Pair of Type I	Failure Region Pair of Type II	Failure Region Pair of TypeIII	Failure Region Pair of TypeIV	Failure Region Pair of Type V	Failure Region Pair of Type VI	Failure Region Pair of Type O	Failure Region Pair Uncor-related
I	-	0.074	0.140± 0.0060	0.042	~~0.792± 0.770~~	~~0.350± 0.212~~	0.430 ± 0.110	0.121 ±0.131
II	-	0.636	-	0.407± 0.216	0.333	-	-	0.206± 0.152
III	0.250	-	0.586± 0.189	0.244± 0.168	0.148± 0.091	-	0.240 ± 0.149	0.145± 0.116
IV	-	0.127± 0.053	0.167	0.70	-	-	-	0.103± 0.080
V	-	-	-	0.298± 0.160	-	-	0.170 ± 0.029	0.170± 0.177
VI	-	0.336± 0.043	0.190± 0.265	0.186± 0.156	-	-	0.50	0.100± 0.070
VII	-	0.106± 0.073	0.2922 ±0.239	0.476± 0.088	0.333	-	0.389 ± 0.096	0.196± 0.130
VIII	0.500	0.438± 0.285	0.75	0.442± 0.182	0.427± 0.269	-	-	0.394± 0.237

7 In entries without Standard Deviation there is only one value. Crossed out entries, contain Average and Standard deviation of only two data values

C. CONCLUSIONS ON CHAPTER III

In this chapter the failure region analysis on the results of the CONFLICT experiment identifies the logical relation of the faults responsible for the observed failure regions.

The testing of the taxonomical clustering hypothesis, section 3.3 to 3.5, implies the observed fault distribution is not uniform. The control logic, case selection, and control state faults appear at a rate about fourteen times the average fault ratio in the program while processing and initialization fault rate is about 30% of the average. Therefore control logic faults and corresponding failure regions actually exhibit taxonomical clustering behavior. This, however, does not correlate with the structural clustering of failure regions observed by Ginn (1991) on the same set of data. This can be justified by the fact that the latter depends strongly on the control and data flow structure of the program, with respect to the corresponding fault location, while the former depends on the type of statement at the fault location.

The results of subsections 3.6 to 3.8 show that about 2/3 of the faults, on the average, appear in the functional modules of Attrition, Communica-

tion, and Observation which include approximately 50% of the program lines. This implies some mild tendency of the failure regions for functional clustering, since some functional modules are indeed more fault-prone than others.

From subsection 3.9 we can see, comparing our results with Ginn's (1991), that for all pairs of structurally correlated failure regions, the clustering metric is, on the average, higher for functionally correlated ones. This is justified by fact that, in a reasonably well structured program, faults on the same group of functional modules will share a common control and data flow path segment more often than faults on different groups, therefore functional and structural correlation cannot be independent.

IV. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

It has been conjectured in the past that fault occurrences tend to converge on program locations, which implies that the revealing of a fault might indicate the existence of others in close proximity of location. However, the evidence so far has been mostly anecdotal. This thesis, together with Ginn's (1991) have been of the first to analyze the relationships between specific faults using structural (Ginn 1991), taxonomical and functional (this thesis) criteria. The results of both support the hypothesis of fault clustering and suggest methods for the exploitation of them in software testing. This chapter summarizes these results, in conjunction with previous work, and points towards the research questions which are open to further investigation.

A. CONCLUSIONS

This thesis, being a sequel to previous work by Ginn (1990), offers strong evidence that failure regions tend to form clusters, not only when structural criteria are used, but taxonomical and functional as well.

The clustering criteria used in this thesis were imposed externally, since both the fault taxonomy and the functional classification of the faults have been independent from the experimental data structure. Therefore, the observed clustering tendency of failure regions can be characterized as ***global*** as opposed to the ***local*** clustering tendency explored b Ginn (1990). In local clustering the criteria are strongly dependent upon the structure of the data at hand (Jain and Dubes 1988). Therefore the Jaccard coefficients used by Ginn readily fall into this category.

The taxonomical clustering behavior suggests that parts of the program prone to control logic, case selection and control state faults, must be the focus of the testing effort. This implies that these parts of a program must also be thoroughly and extensively documented in order to facilitate this focus of effort. The CONFLICT experiment (Shimeall 1991a, b) data analysis suggests that decision points and program control flow have a higher probability of fault occurrence than other locations of the code. A good testing or documentation method, such as decision tables etc., is expected to reduce substantially the rate of this type of faults.

The usefulness of the functional clustering behavior is that known faults in a program imply that the probability of more, undiscovered, faults in the

functional module is higher than the in rest of the code. This provides experimental evidence in support of the anecdotal conjecture that faults tend to attract other faults (Myers 1979). It also suggests that the distribution of faults during the first tests indicates the most fault-prone functional modules, which should be singled out for additional testing.

More often than not the testing effort is exponential, or of higher complexity, in the length of code. The ability to point out the most fault-prone modules or constructs, under the experimentally-verified assumption of functional and taxonomical clustering, represents a substantial reduction to the required amount of testing.

The nature of the cluster formation, and the correlation to Ginns structural clustering, for the two criteria used was markedly different. The taxonomical classification tended to demonstrate a clustering of type C faults (and failure regions) in numbers one order of magnitude higher than the expected when a uniform fault per line of code distribution was assumed.

In order to compare the taxonomical clustering of failure regions to the structural clustering of the same regions, we calculated both the average Jaccard coefficient and the average non-zero Jaccard coefficient (using Ginn's results) for every type of possible taxonomical clustering and every version

of the program. The results in Tables 3.2 and 3.3, in Chapter III, suggest that the structural clustering of failure regions does not depend on taxonomical clustering. This is attributed to the fact that structural clustering depends strongly on the control and data flow structure of a program with respect to the corresponding fault locations while the taxonomical clustering depends mainly on the type of program statement at the said locations.

The functional criterion revealed a tendency of faults to concentrate on certain functional groups of modules (In the CONFLICT case in the Communication, Observation and Attrition groups). A quite interesting result, in this analysis, has been the small scale clustering exhibited by the faults, which tended to occur in high numbers within certain procedures (93) while the majority of the examined procedures (446 total, in all eight versions of CONFLICT) were faultless (cf. Appendix D for a detailed functional fault type distribution). Similar behavior of faults has been reported by Myers (1979) but no explanation was cited. The small-scale clustering suggests that some procedures are more complicated, therefore more fault-prone, than others. In the eight versions of the CONFLICT experiment, the average procedure was 30±20 lines of code in length while the average length of procedures with at least one fault has been 42.5±33 lines and with two or more faults 55±45 lines. This result provides evidence in support of

the above-mentioned argument about procedure complexity and fault clustering correlation, despite the inaccuracies introduced by the fact that only faults with a well-defined location were considered.

Unlike the taxonomical-to-structural clustering lack of correlation, in testing the functional-to-structural clustering correlation in the same as above way, it was found that the average non-zero Jaccard coefficient is systematically higher for functionally correlated pairs than for uncorrelated. This mild correlation is explained by the fact that in a reasonably well-structured program, faults of the same group of functional modules will share a common control and data flow path, will be structurally correlated, more often than faults on different groups.

The use of the number of lines of code (excluding comments but not variable declarations) in our analysis instead of the ***Halstead length*** is due to the ease of use of this metric as well as to unpublished calculations.

B. COMPARISON OF RESULTS TO PREVIOUS WORK

The results of this thesis generally support the findings of previous researchers in the area of relationships between faults. This agreement suggests that the relationships may not be specific to the CONFLICT software experiment but have a more general validity in large software applications.

Myers (1979) postulates that functional clustering exists but provides no further evidence or explanation of the basis for it. This thesis, together with the companion work of Ginn (1990) makes a step toward identifying the specific behavior of faults that result in failure region clustering.

The eminent role of control logic, case selection and control state (type C) faults in program testing has been always emphasized (Beiser 1990, Myers 1979), therefore the importance of taxonomical clustering cannot be easily overlooked.

Briliant et al (1990), analyzing the faults in a 27-version software experiment, conclude that the faults across independent versions not only are not independent but the interdependence is, in many cases, more pronounced

among logically related (which includes taxonomically and functionally related) faults.

Further study of the fault relations on the same version or across versions is required for establishment of the interaction mechanisms.

C. SUGGESTIONS FOR FURTHER RESEARCH

While the results of this work are promising, the experimental population was small and narrowly focused. Additionally, the programs were written by students. Both the method and the results should be validated using a broad range of professionally-produced applications.

One weakness of the method used in this thesis is that in testing the taxonomical clustering hypothesis, a small number of faults (about 10%) cannot be classified and therefore they are not included in the analysis. This is expected to introduce some minor inaccuracies in the results.

Another weakness is the use of seven functional groups of modules in the functional clustering analysis, Movement, Observation, Attrition, Communication, Environment, Restoration and Others. This coarse functional decomposition, imposed by the necessity of a common base for comparison for all eight versions of CONFLICT, blurs the small scale clustering. In

addition, the number of lines per module is quite a weak metric for a procedure complexity and cannot be used effectively as an oracle to single out the most fault-prone modules. However, this simple metric indicates that it is possible to use some normal metric as a predictor of the complexity of a program unit. Further research is required to develop metrics that can serve as oracles for fault prone modules.

Finally, the Jaccard coefficient, based on the number of shared dimensions bounding two failure regions, is not a very efficient measure of structural clustering. A better way to establish a metric of two-fault correlation might be the use of the number of paths through both their respective locations. This method was not used in this thesis since we have been focused on taxonomical and functional rather than structural clustering. However, once certain ambiguities, such as distributed faults, or faults without a specific location, such as a missing function etc., are resolved the proposed metric will directly translate the relationship between two failure regions into two sets of code locations.

APPENDIX A: NOTATION AND SYMBOLS

- ***D_j*:** Partition of the input domain, by path j

- ***$P(j)$*:** Boolean expression equal to the conjunction of all branch predicate constraints along path j. Therefore all elements of D_j satisfy $P(j)$.

- ***Bound(G)*:** The boolean expression which defines failure region G.

- **$\veebar$:** Symbol for exclusive or of boolean expressions.

- ***$S_{j1}S_{j2}..S_{jn}(D')$*:** The mapping of a subset, D', of the input domain to the output range, by a sequence, $S_{j1}S_{j2}..S_{jn}$, of program statements (this sequence is called the ***path product***), where j is a path. Condition evaluations are retained in the path products for consistency. In fact, the ***path products*** of the two segments starting from a decision point (such as an **if** C **then else** construct or a loop exit condition etc) are preceded with the condition C and condition ¬C respectively, depending upon which part of the decision (if or else) results in their execution.

- ***$S_{j,1}S_{j,2}(\, S_{j,l}S_{j,l+1}.S_{j,l+m}\,)^{*}..S_{j,n}$*** : A sequence of program statements, when a subset of them, $S_{j,l}S_{j,l+1}..S_{j,l+m}$, is the body of a loop.

- ***$S_{j,1}S_{j,2}(\, S_{j,l}S_{j,l+1}.S_{j,l+m}\,)^{+}..S_{j,n}$*** : A sequence of program statements, when a subset of them, $S_{j,l}S_{j,l+1}..S_{j,l+m}$, is the body of a loop, which executes at least once.

- ***$S(G_i,G_j)$*:** The simple matching coefficient for failure regions G_i and G_j.

$$S(G_i,G_j) = \frac{a_{00}+a_{11}}{a}$$

where a_{00} stands for the non-bounding dimensions of both failure regions a_{11} for the composite dimensions of G_i and G_j and a for the number of all input dimensions.

- *$J(G_i,G_j)$*: The Jaccard coefficient for failure regions Gi and Gj.

$$J(G_i,G_j) = \frac{a_{11}}{a-a_{00}}$$

where a_{00} stands for the non-bounding dimensions of both failure regions a_{11} for the composite dimensions of G_i and G_j and a for all input dimensions.

- A→B or, equivalently, B→A : Logical implication, A implies B (or ¬A∨B).

- ***Identically participating dimensions***: The dimensions that appear in both boundaries of a pair of failure regions in exactly the same way.

- ***Coincidentally Participating Dimensions***: The dimensions that appear in both boundaries of a pair of failure regions but not in an identical way.

- ***Nonbounding Dimensions***: The dimensions that, for a pair of failure regions, do not appear in the boundaries of both regions. The boundaries these dimensions place on these failure regions are no more restrictive than their entire range of values.

- ***Composite Dimensions:*** Collective name for both Identical and Coincidental dimensions

- ***Chi-Square Statistic*** (χ^2): Statistic used to test whether a significant difference exists between an observed and an expected number of objects[8] (the expected number of objects results from an assumed distribution of objects into categories). The greater the ***chi-square*** statistic the lower the ***confidence*** that the sample data follow the assumed distribution. If there are k categories of objects, O_j is the number of ***observed*** and E_j the number of ***expected*** objects in category j, then the statistic has k-1 degrees of freedom and is equal to:

$$\chi^2 = \sum_{j=1}^{k} \frac{(O_j - E_j)^2}{E_j}$$

[8] Siegel and Castellan 1988

APPENDIX B: TAXONOMICAL FAULT TYPE DISTRIBUTION

In this Appendix we present histograms (Figures B1 to B8, in light grey) of the relative frequency of occurrence of fault types in the eight versions of CONFLICT (Shimeall 1991). The fault types in the histograms are LOOP, CONTROL, PROCESS and EXCEPTION HANDLING. They correspond to the faults of type A, B, C and D of Chapter III (In fact A, B, C, D are just abbreviations).

The fault type frequency histograms are compared with the expected frequency histograms of a simple model which assumes uniform distribution of faults (histograms in dark grey). In figure B9 we present an overall comparison of the observed to expected number of faults ratio, for all eight versions. There is a very sharp peak of the ratio distributions in the CONTROL type of faults, which implies that this type of fault has a frequency of occurrence much greater than the expected by the assumed model.

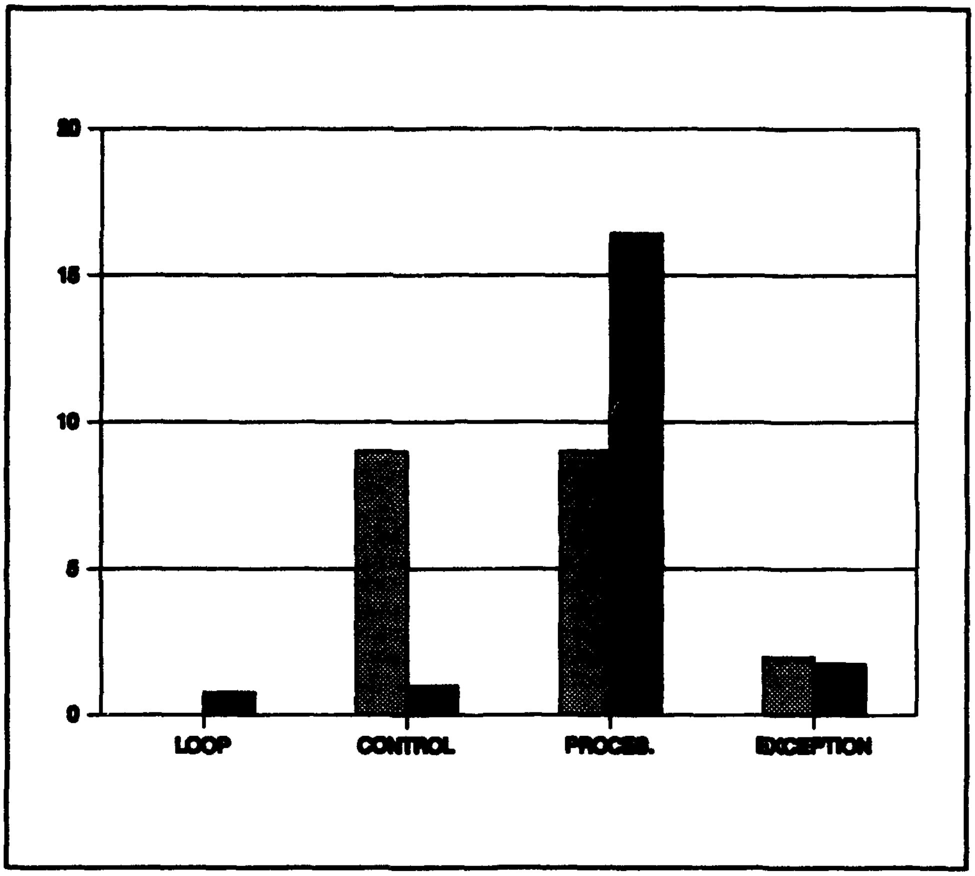

Figure B1: Taxonomical Fault Frequency in Version I (light grey) versus random distribution of faults to program locations (dark grey).

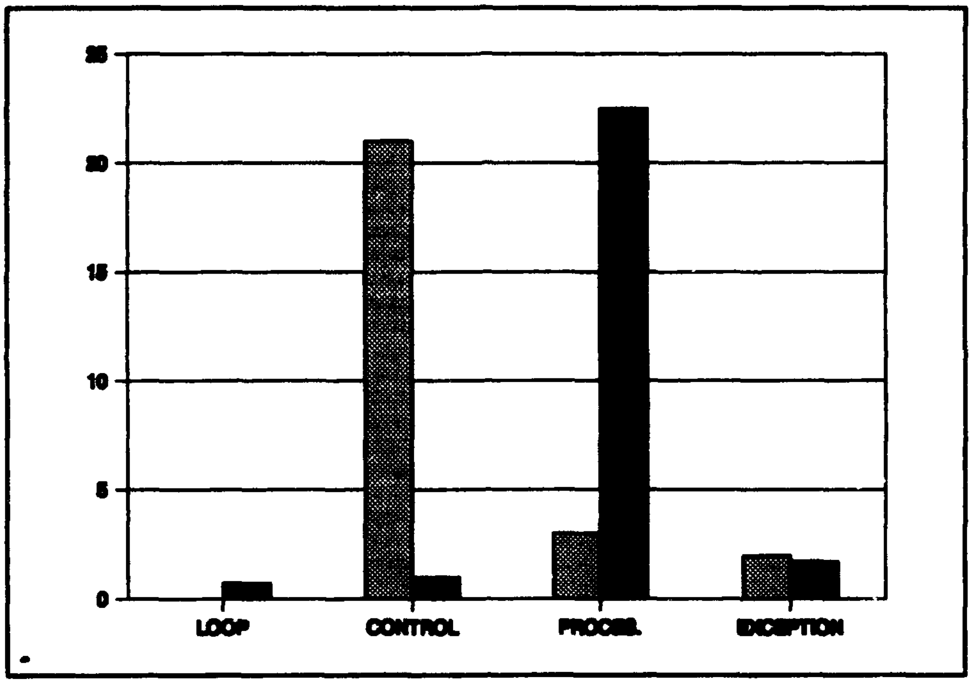

Figure B.2: Taxonomical Fault Frequency in Version II (light grey) versus random distribution of faults to program locations (dark grey).

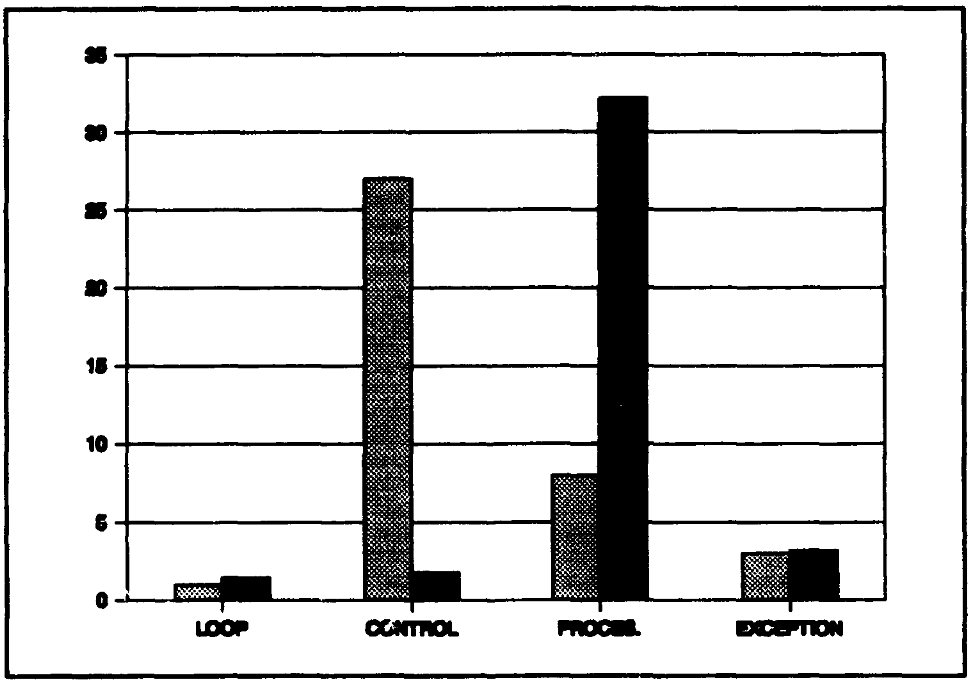

Figure B.3: Taxonomical Fault Frequency in Version III (light grey) versus random distribution of faults to program locations (dark grey).

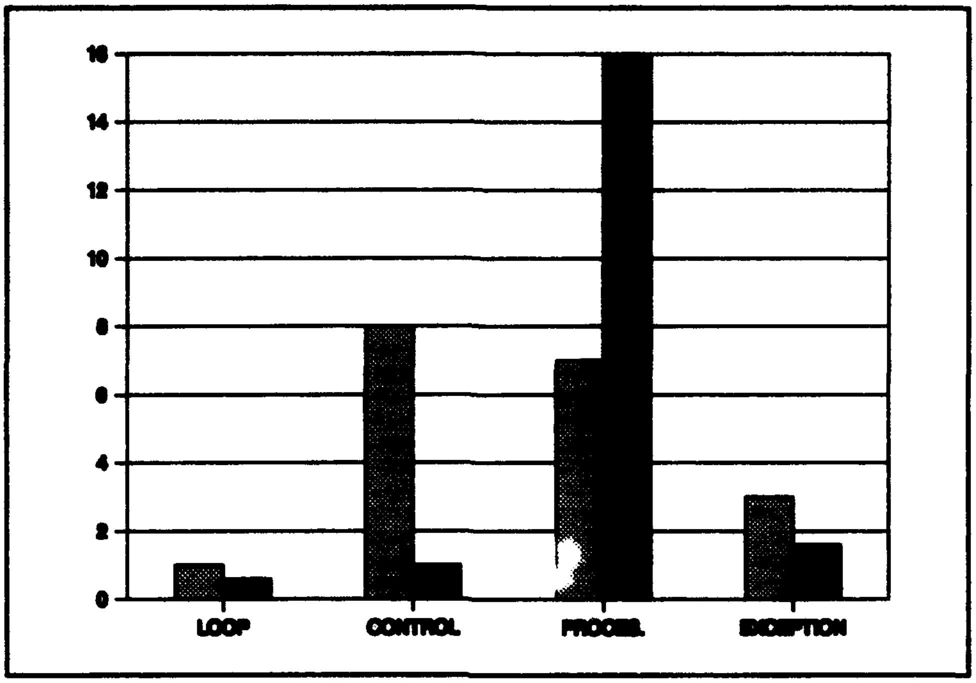

Figure B.4: Taxonomical Fault Frequency in Version IV (light grey) versus random distribution of faults to program locations (dark grey).

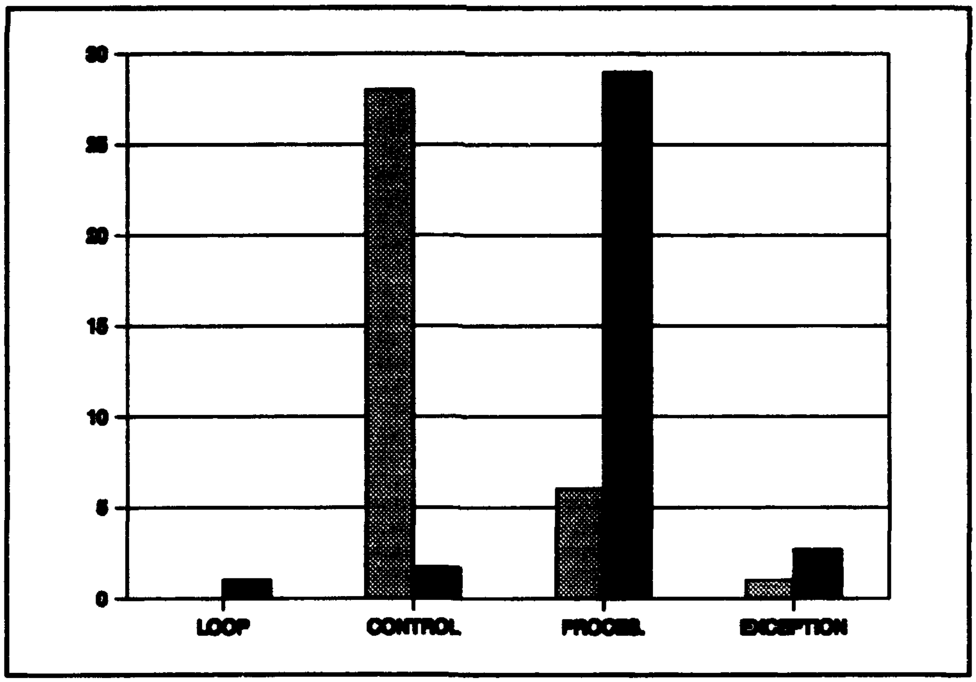

Figure B.5: Taxonomical Fault Frequency in Version V (light grey) versus random distribution of faults to program locations (dark grey).

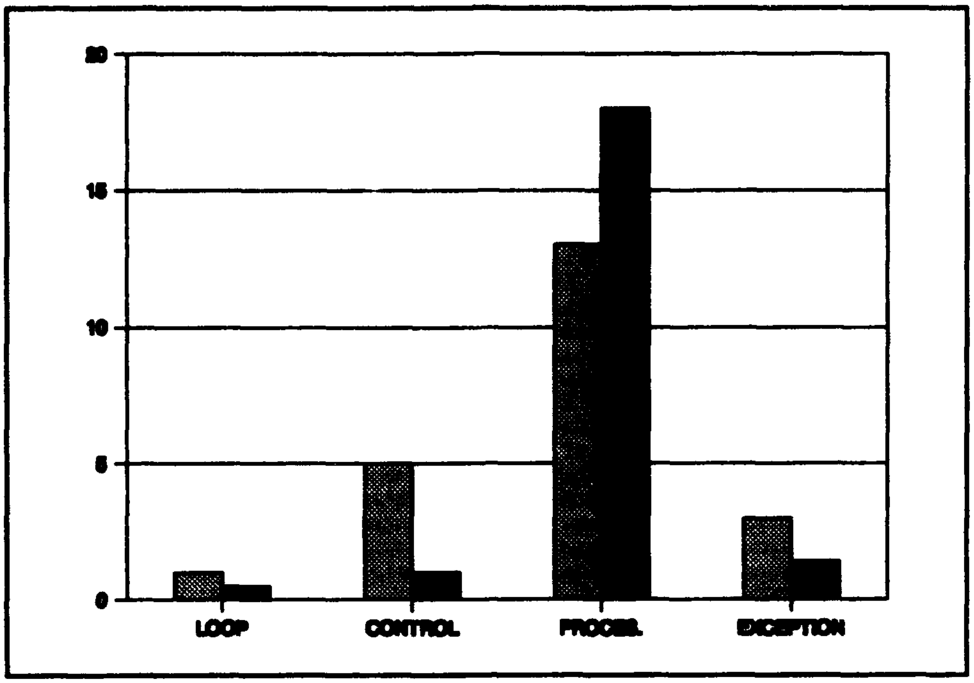

Figure B.6: Taxonomical Fault Frequency in Version VI (light grey) versus random distribution of faults to program locations (dark grey).

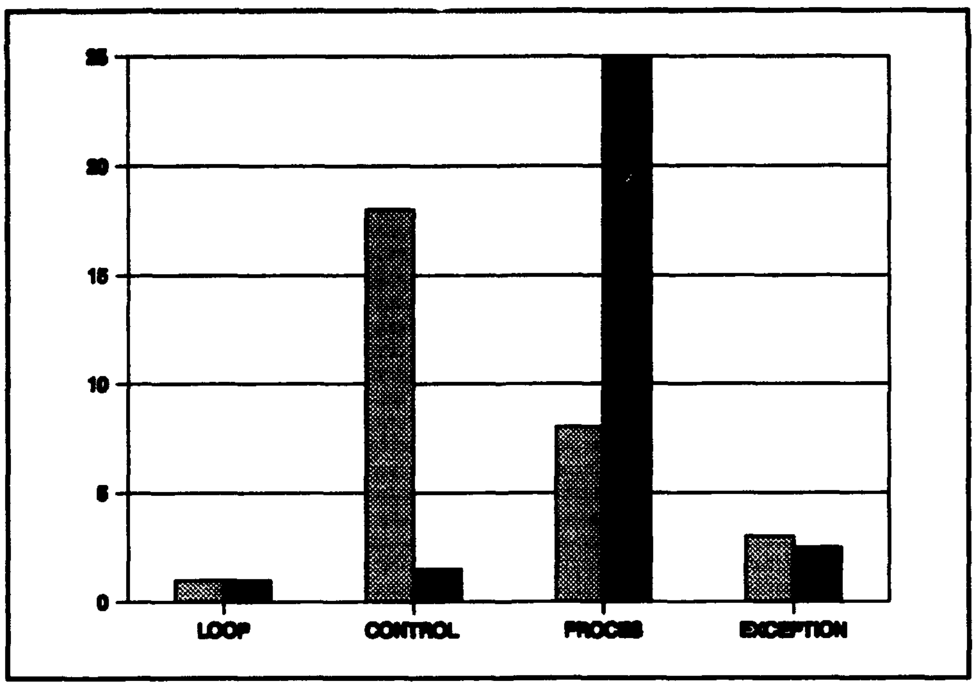

Figure B.7: Taxonomical Fault Frequency in Version VII (light grey) versus random distribution of faults to program locations (dark grey).

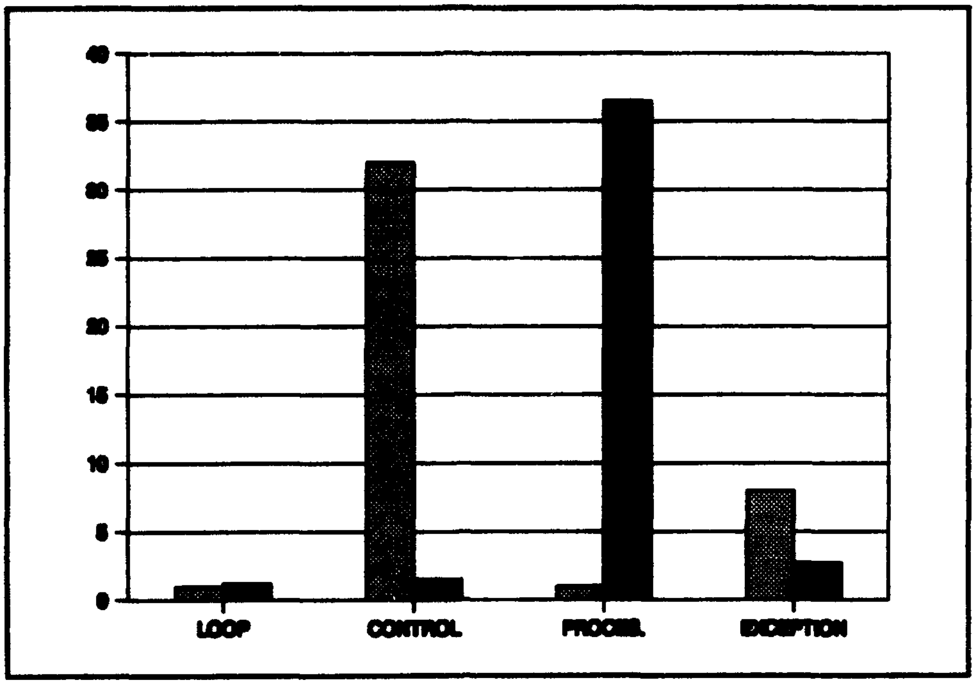

Figure B.8: Taxonomical Fault Frequency in Version VIII (light grey) versus random distribution of faults to program locations (dark grey).

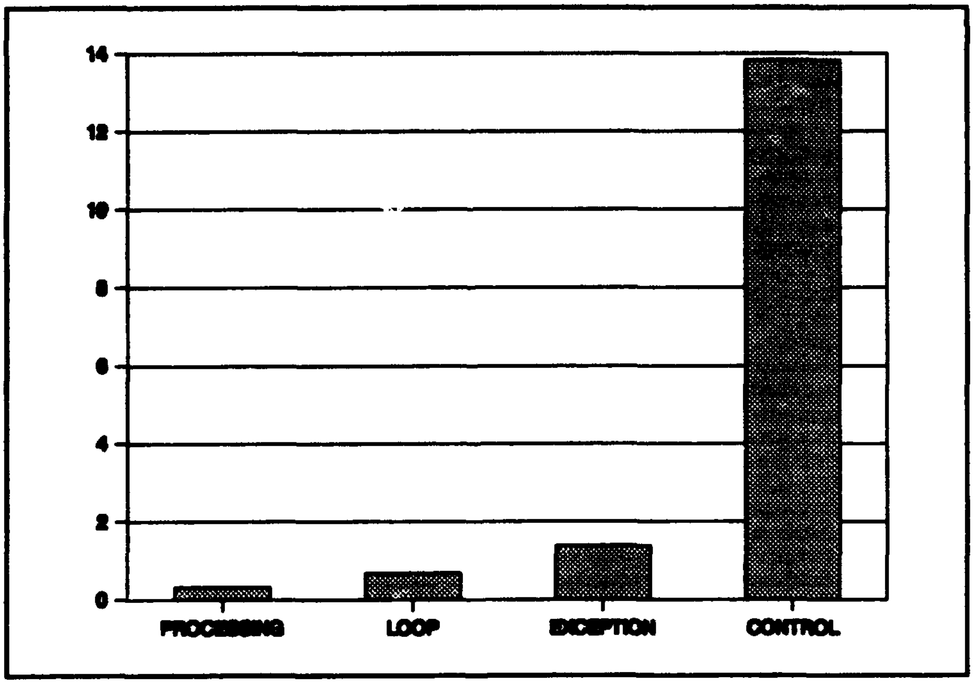

Figure B.9: Actual number of taxonomical faults to expected number of faults ratio for the eight versions of the program.

APPENDIX C: SHARED BOUNDING DIMENSIONS IN TAXONOMICALLY CLUSTERED FAILURE REGIONS

In this Appendix we present a detailed analysis, whether taxonomical clustering of failure regions results in an increased number of shared[9] bounding dimensions.

The results, are presented in the tables C1 to C8. Each of the tables, corresponds to one of the eight versions of the CONFLICT program (Shimeall 1991, 1991b). Each table entry, corresponds to a pair of failure regions of the same version. It is noted that the numbering of the failure regions is not significant in this analysis. It merely represents the order in which the faults and the corresponding failure regions were discovered.

Table entries on the main diagonal, contain the logical cluster identifier (A to D), for the corresponding failure region (cf. Chapter III). Each of the off diagonal entries contains the Jaccard coefficient for the identical

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9 In this analysis, shared dimensions are the ones that correspond to the same predicates, **identical**.

dimensions of the two failure regions labeling the row and column, and the fault type identifier, in case the regions belong to the same logical cluster.

For example, entry (1.2,1.5) contains 0.100./B which means that the Jaccard Coefficient for these failure regions is equal to 0.100., and that both correspond to faults of type B. On the other hand, entry (1.12,1.5) contains 0.154, so the two failure regions have a Jaccard coefficient equal to 0.154, but correspond to different types of faults (D and B respectively, in this case).

TABLE C.1 :
JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.1	1.2	1.3	1.4	1.5	1.6
1.2	0/B	B	-	-	-	-
1.3	0	0	C	-	-	-
1.4	0	0	1.333/C	C	-	-
1.5	0/B	0.100/B	0	0	B	-
1.6	0	0	0/C	0/C	0	C
1.7	0	0	0/C	0/C	0	0/C
1.8	0	0.083/B	0	0	0/B	0
1.9	0/B	0/B	0	0	0/B	0
1.10	0.333	0	0/C	0/C	0	0/C
1.11	0.333	0	0/C	0/C	0	0/C
1.12	0	0.0833	0	0	0.154	0
1.13	0	0	0/C	0/C	0	0/C
1.14	0/B	0/B	0	0	0/B	0

TABLE C.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.7	1.8	1.9	1.10	1.11	1.12	1.13
1.7	C	-	-	-	-	-	-
1.8	0	B	-	-	-	-	-
1.9	0	0.063/B	B	-	-	-	-
1.10	0/C	0	0	C	-	-	-
1.11	0/C	0	0	0.580/C	C	-	-
1.12	0	0	0	0	0	D	-
1.13	0/C	0.182	0.083	0/C	0/C	0	C
1.14	0	0.067/B	0	0	0	0	0.143

TABLE C.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.1	1.2	1.3	1.4	1.5	1.6	1.7
1.17	0.333\B	0\B	0	0	0\B	0	0
1.18	0	0.100	0	0	0.083	0	0
1.19	0	0	0\C	0\C	0.250	0\C	0\C
1.20	0\B	0.056\B	0	0	0.053\B	0	0
1.22	0\B	0\B	0	0	0\B	0	0
1.23	0	0	0\C	0\C	0	0\C	0\C
1.25	0	0	0\C	0\C	0.053	0\C	0\C
1.27	0	0	0\C	0\C	0	0\C	0\C
1.28	0	0	0\C	0\C	0.500	0\C	0\C

TABLE C.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.8	1.9	1.10	1.11	1.12	1.13	1.14
1.17	0\B	0\B	0.500	0.500	0	0	0\B
1.18	0	0	0	0	0.250\D	0	0.111
1.19	0	0.154	0\C	0\C	0.100	0.125\C	0.067
1.20	0.118\B	0.048\B	0	0	0.053	0.133	0.105\B
1.22	0.056\B	0.600\B	0	0	0	0.071	0.048\B
1.23	0	0	0\C	0\C	0.700	0\C	0
1.25	0.050	0.045	0\C	0\C	0	0.118\C	0.109
1.27	0.120	0.036	0\C	0\C	0	0.143\C	0.074
1.28	0	0	0\C	0\C	0.143	0\C	0

TABLE C.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.17	1.18	1.19	1.20
1.17	B	-	-	-
1.18	0	D	-	-
1.19	0	0.100	C	-
1.20	0/B	0.100	0.118	B
1.22	0/B	0	0.067	0.043\B
1.23	0	0.250	0.091\C	0.050
1.25	0	0	0.059\C	0.421
1.27	0	0	0.045\C	0.103
1.28	0	0.071	0.200\C	0.050

TABLE C.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.22	1.23	1.25	1.27	1.28
1.22	B	-	-	-	-
1.23	0	C	-	-	-
1.25	0.042	0.048\C	C	-	-
1.27	0.033	0\C	0.061\C	C	-
1.28	0	0.357\C	0.053\C	0\C	C

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.1	2.2	2.3	2.4	2.5	2.6
2.1	B	-	-	-	-	-
2.2	0/B	B	-	-	-	-
2.3	0/B	0.091/B	B	-	-	-
2.4	0	0.091	0.300	C	-	-
2.5	0	0.067	0.133	0.133/C	C	-
2.6	0	0.091	0.091	0.083	0.063	D
2.7	0.077/B	0/B	0/B	0	0	0
2.8	0.077/B	0/B	0/B	0	0	0
2.10	0/B	0/B	0/B	0	0	0
2.11	0/B	0/B	0/B	0	0	0
2.12	0/B	0/B	0/B	0	0	0
2.13	0/B	0.111/B	0.091/B	0.091	0.154	0
2.14	0/B	0/B	0/B	0	0	0
2.15	0/B	0/B	0/B	0	0	0

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.7	2.8	2.10	2.11	2.12	2.13	2.14	2.15
2.7	B	-	-	-	-	-	-	-
2.8	0.636/B	B	-	-	-	-	-	-
2.10	0/B	0/B	B	-	-	-	-	-
2.11	0/B	0/B	0/B	B	-	-	-	-
2.12	0/B	0/B	0/B	0/B	B	-	-	-
2.13	0/B	0/B	0/B	0/B	0/B	B	-	-
2.14	0/B	0/B	0/B	0/B	0/B	0/B	B	-
2.15	0/B	0/B	0/B	0/B	0/B	0.400/B	0/B	B

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.1	2.2	2.3	2.4	2.5	2.6
2.16	0\B	0\B	0\B	0	0	0
2.17	0\B	0\B	0\B	0	0	0
2.18	0\B	0\B	0\B	0	0	0
2.19	0\B	0\B	0\B	0	0	0
2.20	0\B	0\B	0\B	0	0	0
2.21	0\B	0\B	0\B	0	0	0
2.22	0\B	0\B	0\B	0	0	0
2.23	0\B	0\B	0\B	0	0	0
2.25	0\B	0\B	0\B	0	0	0
2.30	0\B	0.111\B	0.111\B	0.100	0.071	0.333

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.7	2.8	2.10	2.11	2.12	2.13	2.14	2.15
2.16	0\B	0\B	0\B	0\B	0\B	0\B	0.400/B	0.400\B
2.17	0\B	0\B	0\B	0\B	0\B	0\B	0.400/B	0.400\B
2.18	0\B	0\B	0\B	0\B	0\B	0\B	0.400/B	0.400\B
2.19	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.20	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.21	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.22	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.23	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.25	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B
2.30	0\B	0\B	0\B	0\B	0\B	0\B	0\B	0\B

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.16	2.17	2.18	2.19	2.20
2.16	B	-	-	-	-
2.17	0.400/B	B	-	-	-
2.18	0/B	0.400/B	B	-	-
2.19	0/B	0/B	0/B	B	-
2.20	0/B	0/B	0/B	0.571/B	B
2.21	0/B	0/B	0/B	0.571/B	0.571/B
2.22	0/B	0/B	0/B	0.571/B	0.571/B
2.23	0/B	0/B	0/B	0.571/B	0.571/B
2.25	0/B	0/B	0/B	0/B	0/B
2.30	0/B	0/B	0/B	0/B	0/B

TABLE C.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.21	2.22	2.23	2.24	2.30
2.21	B	-	-	-	-
2.22	0.571/B	B	-	-	-
2.23	0.571/B	0.571/B	B	-	-
2.25	0/B	0/B	0/B	B	-
2.30	0/B	0/B	0/B	0/B	B

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.9	3.10
3.1	B	-	-	-	-	-	-	-	-
3.2	0.600-/B	B	-	-	-	-	-	-	-
3.3	0.250-/B	0.286-/B	B	-	-	-	-	-	-
3.4	0/B	0/B	0/B	B	-	-	-	-	-
3.5	0/B	0/B	0/B	0/B	B	-	-	-	-
3.6	0.143	0.200	0	0	0	A	-	-	-
3.7	0.067	0.071	0	0	0	0.071	-	-	-
3.9	0	0	0	0	0	0	0.476	C	-
3.10	0	0	0	0	0.167	0	0	0/C	C
3.11	0.111/B	0.125/B	0.091/B	0/B	0/B	0.125	0.059	0	0
3.12	0.111/B	0.125/B	0/B	0/B	0/B	0.11	0.188	0.087	0
3.13	0	0	0	0	0	0	0	0.042/C	0/C
3.15	0.077	0.083	0.364	0.100	0	0	0	0.040/C	0/C
3.16	0.11	0.125	0.091	0	0	0.125	0.059	0	0
3.17	0\B	0/B	0/B	0/B	0/B	0	0	0	0
3.18	0.067	0.077	0	0	0	0.091	0.714	0.429/C	0/C
3.21	0	0	0	0	0	0	0	0	0
3.22	0.125-/B	0.167-/B	0/B	0/B	0/B	0.200	0.063	0.048	0
3.23	0.182/B	0.200/B	0.077/B	0/B	0.0833/B	0.091	0.111	0.040	0.111

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.18	3.21	3.22	3.23
3.11	B	-	-	-	-	-	-	-	-	-
3.12	0.111-/B	B	-	-	-	-	-	-	-	-
3.13	0	0	C	-	-	-	-	-	-	-
3.15	0.067	0	0/C	C	-	-	-	-	-	-
3.16	0.333	0.111	0	0.067	D	-	-	-	-	-
3.17	0/B	0/B	0	0	0	B	-	-	-	-
3.18	0.063	0.059	0/C	0.056	0.063	0	C	-	-	-
3.21	0	0	0	0	0/D	0	0	D	-	-
3.22	0.111-/B	0.100-/B	0	0	0.111	0/B	0.154	0	B	-
3.23	0.077-/B	0.167-/B	0	0.063	0	0	0.053	0	0.833-/B	B

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.9	3.10
3.24	0.143	0.167	0.167	0	0.286	0	0.071	0/C	0.250-/C
3.25	0.125	0.167	0.250	0	0	0.250	0.067	0/C	0/C
3.26	0/B	0/B	0.125/B	0.125/B	0.571/B	0	0	0	0.167
3.28	0/B	0.125/B	0/B	0.100/B	0.222/B	0.125	0.063	0	0
3.32	0/B	0/B	0.167/B	0/B	0/B	0	0	0	0
3.33	0/B	0/B	0.143/B	0/B	0/B	0	0	0	0
3.34	0/B	0/B	0.143/B	0/B	0/B	0	0	0	0
3.35	0/B	0/B	0.143/B	0/B	0/B	0	0	0	0
3.36	0/B	0/B	0.167/B	0/B	0/B	0	0	0	0
3.37	0/B	0/B	0.143/B	0/B	0/B	0	0	0	0
3.38	0.111/B	0/B	0/B	0.125/B	0.222/B	0	0.067	0	0.167
3.39	0/B	0/B	0/B	0.125/B	0.222/B	0	0	0	0.200
3.40	0/B	0/B	0/B	0.125/B	0.222/B	0	0	0	0.200
3.41	0.071/B	0/B	0/B	0.125/B	0.222/B	0	0	0	0.200
3.42	0/B	0.111/B	0/B	0.126/B	0.222/B	0	0	0	0.200
3.43	0.091/B	0/B	0/B	0.167/B	0/B	0.143	0.118	0.042	0
3.44	0/B	0.083/B	0/B	0/B	0/B	0.091	0.770	0.381	0
3.45	0/B	0/B	0/B	0/B	0.056/B	0	0	0.529	0.381

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.18	3.21	3.22	3.23
3.24	0	0	0/C	0.10-0/C	0	0	0.07-7/C	0	0	0.18 2
3.25	0.111	0.100	0/C	0.09-1/C	0.11 1	0	0.08-3/C	0	0.16 7	0.08 3
3.26	0/B	0/B	0	0.091	0	0/B	0	0	0/B	0.0-83-/B
3.28	0.11-1/B	0.11-1/B	0	0	0.11 1	0/B	0.063	0	0.11-1/B	0.0-83-/B
3.32	0/B	0/B	0	0.100	0	0/B	0	0.33 3	0/B	0/B
3.33	0/B	0/B	0	0.091	0	0/B	0	0.25 0	0/B	0/B
3.34	0/B	0/B	0	0.091	0	0/B	0	0.25 0	0/B	0/B
3.35	0/B	0/B	0	0.091	0	0/B	0	0.25 0	0/B	0/B

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.18	3.21	3.22	3.23
3.36	0/B	0/B	0	0.091	0	0/B	0	0.250	0/B	0/B
3.37	0/B	0/B	0	0.091	0	0/B	0	0.250	0/B	0/B
3.38	0/B	0/B	0	0	0	0/B	0.063	0	0/B	0.08-3/B
3.39	0/B	0/B	0	0	0	0/B	0	0	0/B	0.08-3/B
3.40	0/B	0/B	0	0	0	0/B	0	0	0/B	0.08-3/B
3.41	0/B	0/B	0	0	0	0/B	0	0	0/B	0.08-3/B
3.42	0/B	0/B	0	0	0	0/B	0	0	0/B	0.08-3/B
3.43	0.08-3/B	0.07-7/B	0	0	0.083	0/B	0.143	0	0.111-/B	0.06-7/B
3.44	0.06-7/B	0.06-3/B	0	0	0.067	0/B	0.910	0	0.077-/B	0.05-6/B
3.45	0/B	0.05-0/B	0	0	0	0/B	0.471	0	0/B	0/B

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.24	3.25	3.26	3.28	3.32	3.33	3.34	3.35
3.24	C	-	-	-	-	-	-	-
3.25	0	C	-	-	-	-	-	-
3.26	0.333	0	B	-	-	-	-	-
3.28	0.125	0.111	0.333-/B	B	-	-	-	-
3.32	0	0	0.167/B	0/B	B	-	-	-
3.33	0	0	0.143/B	0/B	0.500/B	B	-	-
3.34	0	0	0.143/B	0/B	0.500/B	0.400/B	B	-
3.35	0	0	0.143/B	0/B	0.500/B	0.400/B	0.400/B	B
3.36	0	0	0.143/B	0/B	0.500/B	0.400/B	0.400/B	0.400/B
3.37	0	0	0.143/B	0/B	0.500/B	0.400/B	0.400/B	0.400/B
3.38	0.286	0	0.375/B	0.200/B	0/B	0/B	0/B	0/B
3.39	0.143	0	0.250/B	0.100/B	0/B	0/B	0/B	0/B
3.40	0.143	0	0.250/B	0.100/B	0/B	0/B	0/B	0/B
3.41	0.143	0	0.250/B	0.100/B	0/B	0/B	0/B	0/B
3.42	0.143	0	0.250/B	0.100/B	0/B	0/B	0/B	0/B
3.43	0	0.125	0/B	0.083/B	0/B	0/B	0/B	0/B
3.44	0.077	0.083	0/B	0.063/B	0/B	0/B	0/B	0/B
3.45	0.059	0	0.059/B	0.053/B	0/B	0/B	0/B	0/B

TABLE C.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.36	3.37	3.38	3.39	3.40	3.41	3.42	3.43	3.44	3.45
3.36	B	-	-	-	-	-	-	-	-	-
3.37	0.400-/B	B	-	-	-	-	-	-	-	-
3.38	0/B	0/B	B	-	-	-	-	-	-	-
3.39	0/B	0/B	0.286/B	B	-	-	-	-	-	-
3.40	0/B	0/B	0.286/B	0.500/B	B	-	-	-	-	-
3.41	0/B	0/B	0.286/B	0.500/B	0.500-/B	B	-	-	-	-
3.42	0/B	0/B	0.286/B	0.500/B	0.500-/B	0.500/B	B	-	-	-
3.43	0/B	0/B	0/B	0.091/B	0.091/B	0.091/B	0.091/B	B	-	-
3.44	0/B	0/B	0.067/B	0/B	0/B	0/B	0/B	0.143/B	B	-
3.45	0/B	0/B	0.105/B	0.053/B	0.053/B	0.053/B	0.053/B	0.053/B	0/B	B

TABLE C.4 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION IV

	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4.9	4.10	4.11	4.12
4.1	C	-	-	-	-	-	-	-	-	-	-
4.2	0	B	-	-	-	-	-	-	-	-	-
4.3	0/C	0.118	C	-	-	-	-	-	-	-	-
4.4	0/C	0	0.045/ C	C	-	-	-	-	-	-	-
4.5	0	0/B	0.063	0.071	B	-	-	-	-	-	-
4.7	0	0/B	0.059	0.071	0.167/ B	B	-	-	-	-	-
4.8	0	0/B	0.167	0.059	0.125/ B	0.111/ B	B	-	-	-	-
4.9	0/C	0	0.063/ C	0.071/ C	0.250	0.167	0.125	C	-	-	-
4.10	0	0/B	0.056	0.063	0/B	0.125/ B	0.091/ B	0.125	B	-	-
4.11	0/C	0.053	0.043/ C	0/C	0	0	0	0/C	0	C	-
4.12	0/C	0	0.063/ C	0.214/ C	0.167	0.125	0.100	0.167/ C	0.100	0/C	C
4.13	0	0	0	0	0	0	0	0	0	0	0
4.14	0/C	0	0/C	0/C	0	0	0	0/C	0	0/C	0/C
4.15	0.500	0/B	0.091	0	0/B	0/B	0.214/ B	0	0/B	0	0
4.16	0	0.071/ B	0	0.188	0/B	0/B	0/B	0	0/B	0	0.077
4.18	0/C	0.100	0/C	0/C	0	0	0	0/C	0	0/C	0/C
4.19	0	0.100	0	0	0	0	0	0	0	0	0
4.21	0	0.071	0	0	0	0	0	0	0	0	0
4.22	0	0/B	0	0	0/B	0/B	0/B	0	0/B	0	0
4.24	0/C	0.100	0/C	0	0	0	0	0/C	0	0/C	0/C
4.26	0/C	0.083	0/C	0	0	0	0	0/C	0	0/C	0/C

TABLE C.4 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION IV

	4.13	4.14	4.15	4.16	4.18	4.19	4.21	4.22	4.24	4.28
4.13	A	-	-	-	-	-	-	-	-	-
4.14	0.800	C	-	-	-	-	-	-	-	-
4.15	0	0	B	-	-	-	-	-	-	-
4.16	0	0	0/B	B	-	-	-	-	-	-
4.18	0	0/C	0	0.091	C	-	-	-	-	-
4.19	0	0	0	0.071	0.125	D	-	-	-	-
4.21	0	0	0	0.063	0.083	0.077/D	D	-	-	-
4.22	0	0	0/B	0	0	0	0	B	-	-
4.24	0	0/C	0	0.083	0.167/C	0.143	0	0	C	-
4.26	0	0/C	0	0.071	0.125/C	0.111	0.077	0	0.60/C	C

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9
5.1	B	-	-	-	-	-	-	-	-
5.2	0\B	B	-	-	-	-	-	-	-
5.3	0\B	0\B	B	-	-	-	-	-	-
5.4	0\B	0.053\B	0\B	B	-	-	-	-	-
5.5	0	0.059	0	0.375	C	-	-	-	-
5.6	0\B	0\B	0.167\B	0\B	0	B	-	-	-
5.7	0\B	0\B	0\B	0\B	0	0\B	B	-	-
5.8	0	0.111	0	0.059	0.067\C	0	0	C	-
5.9	0\B	0.053\B	0\B	0\B	0	0\B	0\B	0	B
5.10	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0.143\B
5.11	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.12	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.13	0	0.050	0	0.083	0.100	0	0	0.056	0
5.15	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.16	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.17	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.18	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B
5.19	0\B	0\B	0\B	0\B	0	0\B	0\B	0	0\B

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.10	5.11	5.12	5.13	5.15	5.16	5.1 7	5.18	5.17
5.10	B	-	-	-	-	-	-	-	-
5.11	0\B	B	-	-	-	-	-	-	-
5.12	0\B	0.200\ B	B	-	-	-	-	-	-
5.13	0	0	0	D	-	-	-	-	-
5.15	0\B	0\B	0\B	0	B	-	-	-	-
5.16	0\B	0\B	0\B	0	0.714 \B	B	-	-	-
5.17	0\B	0\B	0\B	0	0\B	0\B	B	-	-
5.18	0\B	0\B	0\B	0	0\B	0\B	0\B	B	-
5.19	0\B	0\B	0\B	0	0\B	0\B	0\B	0\B	B

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
5.20	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.21	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.22	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.23	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.24	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.25	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.26	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.27	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.28	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.30	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.31	0	0	0	0	0/C	0	0	0
5.32	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.33	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.34	0	0	0	0	0/C	0	0	0
5.35	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B
5.37	0	0	0	0	0	0	0	0
5.39	0	0	0	0	0	0	0	0
5.40	0	0	0	0	0	0	0	0

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.9	5.10	5.11	5.12	5.13	5.15	5.16	5.17	5.18	5.19
5.20	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.21	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.22	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.23	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.24	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.25	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.26	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.27	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.28	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.30	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.31	0	0	0	0	0	0.130	0.261	0	0	0
5.32	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.33	0/B	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B
5.34	0	0	0	0	0	0	0	0	0	0
5.35	0/B	0/B	0/B	0/B	0	0.040/B	0.040/B	0/B	0/B	0/B
5.37	0	0	0	0	0	0	0	0	0	0
5.39	0	0	0	0	0	0.083	0.083	0	0	0
5.40	0	0	0	0	0	0	0	0	0	0

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.19	5.20	5.21	5.22	5.23	5.24	5.25	5.26	5.27
5.20	0/B	B	-	-	-	-	-	-	-
5.21	0.444/ B	0/B	B	-	-	-	-	-	-
5.22	0/B	0.286/B	0/B	B	-	-	-	-	-
5.23	0.444/ B	0/B	0.444/ B	0/B	B	-	-	-	-
5.24	0/B	0.286/B	0/B	0.286/ B	0/B	B	-	-	-
5.25	0.444/ B	0/B	0.444/ B	0/B	0.444/ B	0/B	B	-	-
5.26	0/B	0.286/B	0/B	0.286/ B	0/B	0.286/ B	0/B	B	-
5.27	0.444/ B	0/B	0.444/ B	0/B	0.444/ B	0/B	0.444 /B	0/B	B
5.28	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B
5.30	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B
5.31	0	0	0	0	0	0	0	0	0
5.32	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B
5.33	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B
5.34	0	0	0	0	0	0	0	0	0
5.35	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B
5.37	0	0	0	0	0	0	0	0	0
5.39	0	0	0	0	0	0	0	0	0
5.40	0	0	0	0	0	0	0	0	0

TABLE C5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.28	5.30	5.31	5.32	5.33	5.34	5.35	5.37	5.39
5.28	B	-	-	-	-	-	-	-	-
5.30	0/B	B	-	-	-	-	-	-	-
5.31	0	0	C	-	-	-	-	-	-
5.32	0/B	0/B	0/B	B	-	-	-	-	-
5.33	0/B	0/B	0/B	0/B	B	-	-	-	-
5.34	0	0	0/C	0	0	C	-	-	-
5.35	0/B	0/B	0.053/ B	0/B	0/B	0.214/ B	B	-	-
5.37	0	0	0	0	0	0	0	-	-
5.39	0	0	0.125	0	0	0	0.063	0	-
5.40	0	0	0	0	0	0	0	0	0.053

TABLE C.6 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VI

	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8
6.1	C	-	-	-	-	-	-	-
6.2	0	B	-	-	-	-	-	-
6.3	0.357/ C	0	C	-	-	-	-	-
6.4	0	0	0	A	-	-	-	-
6.5	0/C	0	0/C	0	C	-	-	-
6.6	0.077	0	0.063	0	0	D	-	-
6.7	0.056/ C	0	0.048/ C	0	0/C	0.091	C	-
6.8	0.167/ C	0.143	0/C	0	0/C	0.091	0.500/ C	C
6.9	0.059/C	0	0.050/C	0	0/C	0.100	0.286/C	0.286/C
6.11	0/C	0.143	0/C	0	0/C	0	0/C	0/C
6.12	0/C	0	0/C	0	0/C	0	0/C	0/C
6.13	0	0/B	0	0	0	0	0	0
6.14	0/C	0	0/C	0	0/C	0	0/C	0/C
6.15	0/C	0.111	0/C	0	0/C	0	0/C	0/C
6.16	0.364/C	0	0.286/C	0	0/C	0.125	0.083/C	0.250/C
6.17	0.056	/B	0.048	0	0	0.083	0.091	0.091
6.18	0/C	0	0/C	0	0/C	0	0/C	0/C

TABLE C.6 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VI

	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8
6.20	0	0/B	0	0	0	0	0	0
6.23	0.056	0/B	0.048	0	0	0.091	0.091	0.091
6.24	0/C	0	0/C	0	0/C	0	0/C	0/C

TABLE C.6 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VI

	6.9	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18	6.20	6.23	6.24
6.9	C	-	-	-	-	-	-	-	-	-	-	-
6.11	0/C	C	-	-	-	-	-	-	-	-	-	-
6.12	0/C	0/C	C	-	-	-	-	-	-	-	-	-
6.13	0	0	0	B	-	-	-	-	-	-	-	-
6.14	0/C	0/C	0.059/C	0	C	-	-	-	-	-	-	-
6.15	0/C	0.143/C	0.071/C	0	0/C	C	-	-	-	-	-	-
6.16	0.071/C	0/C	0/C	0	0/C	0/C	C	-	-	-	-	-
6.17	0.067	0	0	0/B	0	0	0.077	B	-	-	-	-
6.18	0/C	0/C	0.067/C	0	0.400/C	0/C	0/C	0	C	-	-	-
6.20	0	0	0	0/B	0	0	0	0/B	0	B	-	-
6.23	0.071	0	0	0/B	0	0	0.077	0.73/B	0	0/B	B	-
6.24	0/C	0.071/C	0.118/C	0	0.278/C	0.063/C	0/C	0	0.467/C	0	0	C

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.1	7.2	7.3	7.4	7.5	7.6	7.7
7.1	B	-	-	-	-	-	-
7.2	0.083/B	B	-	-	-	-	-
7.3	0.083/B	0.818/B	B	-	-	-	-
7.4	0/B	0/B	0/B	B	-	-	-
7.5	0.167	0	0	0.071	C	-	-
7.6	0/B	0/B	0/B	0/B	0	B	-
7.7	0/B	0/B	0/B	0/B	0	0.333/B	B
7.8	0/B	0/B	0/B	0/B	0	0.333/B	0.500/B
7.9	0	0	0	0.333	0	0	0
7.10	0	0.231	0.214	0	0/C	0	0
7.11	0	0	0	0	0	0.200	0.167
7.12	0/B	0/B	0/B	0/B	0	0/B	0/B
7.13	0	0	0	0	0	0	0
7.14	0	0	0	0.143	0/C	0	0
7.15	0.200	0.091	0.083	0	0/C	0	0
7.16	0/B	0/B	0/B	0/B	0	0/B	0/B

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.8	7.9	7.10	7.11	7.12	7.13	7.14	7.15	7.16
7.8	B	-	-	-	-	-	-	-	-
7.9	0	-	-	-	-	-	-	-	-
7.10	0	0	C	-	-	-	-	-	-
7.11	0.167	0	0	D	-	-	-	-	-
7.12	0/B	0	0	0	B	-	-	-	-
7.13	0	0	0	0	0	A	-	-	-
7.14	0	0	0/C	0	0.100	0	C	-	-
7.15	0	0	0/C	0	0	0	0/C	C	-
7.16	0/B	0	0	0	0/B	0	0	0	B

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.1	7.2	7.3	7.4	7.5	7.6
7.17	0/B	0/B	0/B	0/B	0	0/B
7.18	0/B	0/B	0/B	0/B	0	0/B
7.19	0/B	0/B	0/B	0/B	0	0/B
7.20	0/B	0/B	0/B	0/B	0	0/B
7.21	0/B	0/B	0/B	0/B	0	0/B
7.22	0/B	0/B	0/B	0/B	0	0/B
7.23	0/B	0/B	0/B	0/B	0	0/B
7.24	0/B	0/B	0/B	0/B	0	0/B
7.25	0/B	0/B	0/B	0/B	0	0/B
7.27	0.100	0.200	0.273	0	0	0
7.28	0	0	0	0	0/C	0
7.29	0.077	0.455	0.417	0	0/C	0
7.32	0.048	0.038	0.037	0	0/C	0
7.33	0	0	0	0	0	0.143
7.35	0.077	0.333	0.400	0	0/C	0

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.7	7.8	7.9	7.10	7.11	7.12	7.13	7.14	7.15	7.16
7.17	0/B	0/B	0	0	0	0/B	0	0	0	0.400/B
7.18	0/B	0/B	0	0	0	0/B	0	0	0	0.400/B
7.19	0/B	0/B	0	0	0	0/B	0	0	0	0.400/B
7.20	0/B	0/B	0	0	0	0/B	0	0	0	0.400/B
7.21	0/B	0/B	0	0	0	0/B	0	0	0	0/B
7.22	0/B	0/B	0	0	0	0/B	0	0	0	0/B
7.23	0/B	0/B	0	0	0	0/B	0	0	0	0/B
7.24	0/B	0/B	0	0	0	0/B	0	0	0	0/B
7.25	0/B	0/B	0	0	0	0/B	0	0	0	0/B
7.27	0	0	0	0.077	0/D	0	0	0	0.111	0
7.28	0	0	0	0/C	0	0	0	0/C	0/C	0
7.29	0	0	0	0.231/C	0	0	0	0/C	0.083/C	0
7.32	0	0	0	0/C	0	0	0	0/C	0.050/C	0
7.33	0.125	0.125	0	0	0.333/D	0	0	0	0	0
7.35	0	0	0	0.200/C	0	0	0	0/C	0.091/C	0

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.17	7.18	7.19	7.20	7.21
7.17	B	-	-	-	-
7.18	0.400/B	B	-	-	-
7.19	0.400/B	0.400/B	B	-	-
7.20	0.400/B	0.400/B	0.400/B	B	-
7.21	0/B	0/B	0/B	0/B	B
7.22	0/B	0/B	0/B	0/B	0.571/B
7.23	0/B	0/B	0/B	0/B	0.571/B
7.24	0/B	0/B	0/B	0/B	0.571/B
7.25	0/B	0/B	0/B	0/B	0.429/B
7.27	0	0	0	0	0
7.28	0	0	0	0	0
7.29	0	0	0	0	0
7.32	0	0	0	0	0
7.33	0	0	0	0	0
7.35	0	0	0	0	0

TABLE C.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.22	7.23	7.24	7.25	7.27	7.28	7.29	7.32	7.33	7.35
7.22	B	-	-	-	-	-	-	-	-	-
7.23	0.571/ B	B	-	-	-	-	-	-	-	-
7.24	0.571/ B	0.571/ B	B	-	-	-	-	-	-	-
7.25	0.429/ B	0.429/ B	0.429/ B	B	-	-	-	-	-	-
7.27	0	0	0	0	D	-	-	-	-	-
7.28	0	0	0	0	0	C	-	-	-	-
7.29	0	0	0	0	0.182	0/C	C	-	-	-
7.32	0	0	0	0	0.125	0/C	0.037/ C	C	-	-
7.33	0	0	0	0	0/D	0	0	0	D	-
7.35	0	0	0	0	0.200	0/C	0.333/ C	0.034/ C	0	C

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8
8.1	D	-	-	-	-	-	-	-
8.2	0/D	D	-	-	-	-	-	-
8.3	0/D	0.500/ D	D	-	-	-	-	-
8.4	0/D	0.143/ D	0.250/ D	D	-	-	-	-
8.5	0	1.00	0.500	0.429	-	-	-	-
8.6	0	0.500	0	0.125	0.500	B	-	-
8.7	0	0.333	0.667	0.111	0.333	0.667	C	-
8.8	0.250/D	0/D	0/D	0/D	0	0	0	D
8.9	0.125	0	0	0	0	0	0	0
8.11	0	0.333	0.200	0.100	0.250	0.200/B	0.167	0.667
8.12	0	0	0	0	0	0/B	0	0
8.13	0.750	0	0	0	0	0/B	0	0.500
8.14	0.222/D	0/D	0/D	0/D	0	0	0	0/D
8.15	0.750	0	0	0	0	0/B	0	1.00
8.18	0.143	0	0	0	0	0/B	0	0
8.19	0.286	0	0	0	0	0/B	0	0.500
8.23	0	0.500	0.333	0.111	0.333	0.333/B	0.250	1.00
8.25	0	0	0	0	0	0/B	0	0
8.26	0	0	0	0	0	0/B	0	0

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.9	8.11	8.12	8.13	8.14	8.15	8.18	8.19	8.23	8.25	8.26
8.9	A	-	-	-	-	-	-	-	-	-	-
8.11	0	B	-	-	-	-	-	-	-	-	-
8.12	0	0/B	B	-	-	-	-	-	-	-	-
8.13	0.167	0/B	0/B	B	-	-	-	-	-	-	-
8.14	0.091	0	0	0.125	D	-	-	-	-	-	-
8.15	0.200	0/B	0/B	1.00	0.429	B	-	-	-	-	-
8.18	0	0/B	0/B	0	0.100	0.250\B	B	-	-	-	-
8.19	0.125	0.167/B	0/B	0.400	0.200	0.750\B	0\B	B	-	-	-
8.23	0	0.500/B	0/B	0	0	0\B	0\B	0\B	B	-	-
8.25	0	0/B	0/B	0	0	0\B	0\B	0\B	0\B	B	-
8.26	0	0/B	0/B	0	0	0\B	0\B	0\B	0\B	0.667\B	B

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9
8.27	0	0	0	0	0	0/B	0	0	0
8.28	0	0	0	0	0	0/B	0	0	0
8.29	0	0	0	0	0	0/B	0	0	0
8.30	0	0	0	0	0	0/B	0	0	0
8.31	0	0	0	0	0	0/B	0	0	0
8.32	0	0	0	0	0	0/B	0	0	0
8.33	0	0	0	0	0	0/B	0	0	0
8.34	0	0	0	0	0	0/B	0	0	0
8.36	0.333/D	0/D	0/D	0/D	0	0	0	0.143/D	0.091
8.37	0.600/D	0/D	0/D	0/D	0	0	0	0.333/D	0.143
8.38	0.600	0	0	0	0	0/B	0	0.333	0.143
8.40	0.500	0	0	0	0	0/B	0	0.250	0.125
8.41	0.500	0	0	0	0	0/B	0	0.333	0.143
8.42	0	0	0.500	0.143	1.00	0.500/B	0.333	0	0
8.44	0.333	0	0	0	0	0/B	0	0.167	0.100
8.45	0.200	1.00	0.333	0.125	0.500	0.333/B	0.250	0	0
8.46	0.333	0	0	0	0	0/B	0.333	0.333	0.200
8.48	0.500	0	0.500	0.143	1.00	0.500/B	0	0	0
8.50	0	0	0	0	0	0/B	0	0	0

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.11	8.12	8.13	8.14	8.15	8.18	8.19	8.23	8.25	8.26
8.27	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0.500/B	0.500/B
8.28	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0.667/B	0.667/B
8.29	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0.400/B	0.400/B
8.30	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B
8.31	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B
8.32	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B
8.33	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B
8.34	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B
8.36	0	0	0.250	0.333/D	0.571	0.100	0.300	0	0	0
8.37	0	0	0.50	0.222/D	1.00	0.167	0.333	0	0	0
8.38	0/B	0/B	0.500/B	0.222	1.00/B	0.167/B	0.33/B	0/B	0/B	0/B
8.40	0/B	0/B	0.400/B	0.300	1.00/B	0.143/B	0.429/B	0/B	0/B	0/B
8.41	0/B	0/B	0.500/B	0.333	0/B	0.167/B	0.500/B	0/B	0/B	0/B
8.42	0.333/B	0/B	0/B	0	0/B	0/B	0/B	0.500/B	0/B	0/B
8.44	0/B	0/B	0.286/B	0.250	0.667/B	0.111/B	0.429/B	0/B	0/B	0/B
8.45	0.250/B	0/B	0/B	0.125	0.500/B	0.250/B	0/B	0.33/B	0/B	0/B
8.46	0/B	0/B	0.500/B	0.333	1.00/B	0/B	0.500/B	0/B	0/B	0/B
8.48	0.333/B	0/B	0/B	0	0/B	0/B	0/B	0.500/B	0/B	0/B
8.50	0/B	0/B	0/B	0	0/B	0/B	0/B	0/B	0/B	0/B

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.27	8.28	8.29	8.30	8.31	8.32	8.33
8.27	B	-	-	-	-	-	-
8.28	0.500/B	B	-	-	-	-	-
8.29	0.333/B	0.400/B	B	-	-	-	-
8.30	0/B	0/B	0/B	B	-	-	-
8.31	0/B	0/B	0/B	0.444/B	B	-	-
8.32	0/B	0/B	0/B	0.667/B	0.500/B	B	-
8.33	0/B	0/B	0/B	0.667/B	0.500/B	0.800/B	B
8.34	0/B	0/B	0/B	0.364/B	0.308/B	0.400/B	0.400/B
8.36	0	0	0	0	0	0	0
8.37	0	0	0	0	0	0	0
8.38	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.40	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.41	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.42	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.44	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.45	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.46	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.48	0/B	0/B	0/B	0/B	0/B	0/B	0/B
8.50	0/B	0/B	0/B	0/B	0/B	0/B	0/B

TABLE C.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.34	8.36	8.37	8.38	8.40	8.41	8.42	8.44	8.45	8.46	8.48	8.50
8.34	B	-	-	-	-	-	-	-	-	-	-	-
8.36	0/B	D	-	-	-	-	-	-	-	-	-	-
8.37	0	0.429/D	D	-	-	-	-	-	-	-	-	-
8.38	0/B	0.429	1.00	B	-	-	-	-	-	-	-	-
8.40	0/B	0.500	0.750	0.750/B	B	-	-	-	-	-	-	-
8.41	0/B	0.444	0.600	0.600/B	0.833/B	B	-	-	-	-	-	-
8.42	0/B	0	0	0/B	0/B	0/B	B	-	-	-	-	-
8.44	0/B	0.364	0.375	0.375/B	0.444/B	0.500/B	0/B	B	-	-	-	-
8.45	0/B	0.125	0.250	0.250/B	0.200/B	0.250/B	1.000/B	0.143/B	B	-	-	-
8.46	0/B	0.333	0.400	0.400/B	0.500/B	0.600/B	0/B	0.375/B	0.667/B	B	-	-
8.48	0/B	0	0	0/B	0/B	0/B	0/B	0/B	1.00/B	0/B	B	-
8.50	0.083/B	0	0	0/B	0/B	0/B	0/B	0/B	0/B	0/B	0/B	B

APPENDIX D: FUNCTIONAL FAULT TYPE DISTRIBUTION

In this Appendix we present (Tables D.1 to D.8) the relative frequency of occurrence of functional fault types in the eight versions of CONFLICT (Shimeall 1991b). The fault types are classified in types O, I, II, III, and VI according to the discussion in Section B.7 of Chapter III .

Some of the faults included in the failure region library by Shimeall (1991a) do not have a specific location and, therefore, cannot be assigned to any specific program module. However, it is possible by their description to determine which part of the CONFLICT function each of them affects. These faults occupy the generic entries (labeled as Others, movement,.. etc) in bold type that precede each functional group of program modules.

Faults that have been assigned to multiple functional groups contribute to the fault count of each group by an appropriate fraction of fault. For example, a fault distributed in three groups, will contribute to the fault count of each group by 1/3.

The observed fault type frequencies are compared with the expected frequencies of a simple model that assumes uniform distribution of faults as in Appendix B.

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I[10]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	561	-	8/26	6.2	0.24
Conflict	O	94	-	-	-	-
Ceiling	O	18	-	-	-	-
MinI	O	7	-	-	-	-
MinR	O	7	-	-	-	-
MaxIR	O	7	-	-	-	-
Outside Range	O	17	-	-	-	-
VerifyInput	O	20	1.17	-	-	-
Check Params	O	32	1.7, 1.6	-	-	-
Check Army Values	O	115	1.10, 1.11	-	-	-
Prepare Output	O	49	1.23, 1.1	-	-	-
Initialization	O	114	-	-	-	-
Update Army Values	O	24	-	-	-	-
Update	O	71	1.2	-	-	-

10 The fault rate is 26/2352 = 0.01105 faults per line (including data declarations in the line count)

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Movement	I	**160**	-	1/26	1.77	0.068
BatVelocV	I	23	-	-	-	-
AltitudeZ	I	30	-	-	-	-
DistD	I	4	-	-	-	-
Position	I	72	1.8	-	-	-
Movement	I	31	-	-	-	-
Observation	II	**240**	-	3/26	2.65	0.10
SizeListLoc	II	14	-	-	-	-
HeightH	II	20	-	-	-	-
FindAngle	II	21	-	-	-	-
First Condition	II	41	-	-	-	-
Second Condition	II	25	-	-	-	-
Visual Contrast	II	10	-	-	-	-
ObservJam	II	18	1.27	-	-	-
Third Condition	II	27	-	-	-	-
Observation	II	64	1.14, 1.26	-	-	-

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Attrition	III	355	-	4/26	3.92	0.151
Attrition	III	10	1.13	-	-	-
Set Fire Upon Coords	III	44	1.13, 1.16. 1.15	-	-	-
Assign LL Coords	III	21	-	-	-	-
KilledK	III	46	-	-	-	-
Num Killers NK	III	28	-	-	-	-
Killers AvailKA	III	39	-	-	-	-
Times Killers Used KU	III	40	-	-	-	-
Total Weap In Use NW	III	51	1.20	-	-	-
ClearDead Squads	III	30	-	-	-	-
For Each Weap	III	46	-	-	-	-
Communica tion	IV	678	-	3/26	7.49	0.288
Check ComMsg	IV	21	-	-	-	-
Send Reports	IV	47	-	-	-	-

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Communication	IV	10	-	-	-	-
Total Squads SendingNS	IV	22	-	-	-	-
TotalSquads ReceivNR	IV	22	-	-	-	-
TotalSquads Jamming	IV	22	-	-	-	-
TotalSquads Processing NR	IV	22	-	-	-	-
PutIntoList	IV	42	1.22	-	-	-
SendMsgs	IV	121	-	-	-	-
Process Command Messages	IV	29	-	-	-	-
Process Report Messages	IV	69	-	-	-	-
Msg Receipt DelayRd	IV	52	-	-	-	-
ManipProcess List	IV	78	-	-	-	-
ManipMsg Queue	IV	33	-	-	-	-

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
PutMsg On Sent LL	IV	22	-	-	-	-
Instantiate CommandMsg	IV	66	1.25, 1.19	-	-	-
Environment	V	143	-	4/26	1.58	0.061
Chech Weather	V	26	1.3, 1.4	-	-	-
TerrMove TM	V	25	1.18, 1.12	-	-	-
Weather SevFactor WF	V	22	-	-	-	-
Weather ObservWO	V	12	-	-	-	-
Weather MoveWM	V	12	-	-	-	-
Slope Intensity IS	V	24	-	-	-	-
Altitude IntensityIA	V	7	-	-	-	-
IntensityLocIL	V	6	-	-	-	-
Location Intensity BI	V	9	-	-	-	-

TABLE D.1 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION I

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Restoration	VI	215	-	3/26	2.38	0.092
Squad Alive	VI	4	1.9	-	-	-
Bat Alive	VI	16	-	-	-	-
Restoration	VI	8	-	-	-	-
TotalRestoredCasualtiesFF	VI	36	-	-	-	-
Coefficient	VI	28	-	-	-	-
MunSquads Restoring NF	VI	19	-	-	-	-
Restore SuppAmtFS	VI	23	-	-	-	-
Restore FactorF	VI	54	1.5, 1.28	-	-	-
CalcEndurE	VI	27	-	-	-	-

TABLE D.2 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION II[11]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	184	-	0/26	3.11	0.119
Conflict	O	96	-	-	-	-
MinReal	O	7	-	-	-	-
MinInt	O	7	-	-	-	-
Max	O	7	-	-	-	-
MaxInt	O	7	-	-	-	-
Roof	O	11	-	-	-	-
Floor	O	9	-	-	-	-
Output	O	5	-	-	-	-
Simulation	O	17	-	-	-	-
Initialization	O	18	-	-	-	-
Movement	I	243	2.10, 2.11, 2.13	3/26	4.10	0.158
TMove	I	25	-	-	-	-
ScaleSquad	I	67	-	-	-	-
Positioning	I	16	-	-	-	-
Velocity	I	21	-	-	-	-

11 The fault rate is 26/1540 = 0.0169 faults per line (including data declarations in the line count)

TABLE D.2 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION II

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Xmove	I	9	-	-	-	-
Ymove	I	9	-	-	-	-
Movement	I	37	-	-	-	-
PosInit	I	14	-	-	-	-
MoveInit	I	11		-	-	-
MoveOut	I	34	-	-	-	-
Observation	II	227	2.15, 2.26	5/26	3.832	0.147
Angle Big Enough	II	60	2.7, 2.8	-	-	-
Slope	II	4	-	-	-	-
Can J Seek	II	9	-	-	-	-
Observation	II	50	-	-	-	-
Calc Contrast	II	24	-	-	-	-
FindPt	II	5	2.12	-	-	-
No Obstacles	II	20	-	-	-	-
NotObs Jammed	II	20	-	-	-	-
OJamming	II	25	-	-	-	-
ObsInit	II	10	-	-	-	-

TABLE D. 2 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION II

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Attrition	III	**287**	-	0/26	4.85	0.186
Attrition	III	5	-	-	-	-
AttritInflict	III	9	-	-	-	-
Weapons	III	63	-	-	-	-
FireCoord	III	56	-	-	-	-
Suffering	III	94	-	-	-	-
AttritInit	III	35	-	-	-	-
AttritOut	III	25	-	-	-	-
Communic ation	IV	**369**	2.16,2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23	14/26	6.23	0.240
Communic ation	IV	9	2.4, 2.25	-	-	-
Update Comm	IV	59	-	-	-	-
AddToQ	IV	21	-	-	-	-
Create Reports	IV	41	2.1	-	-	-
Create Commands	IV	28	2.2	-	-	-
Pull FromQ	IV	32	-	-	-	-
Relay Messages	IV	55	2.3	-	-	-
Consume Reports	IV	58	-	-	-	-

TABLE D. 2 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION II

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Consume Commands	IV	51	2.5	-	-	-
CommInit	IV	15	-	-	-	-
Environment	V	141	-	3/26	2.38	0.092
Dist	V	4	-	-	-	-
Alt	V	25	2.30, 2.6, 2.31	-	-	-
PosIntens	V	31	-	-	-	-
WTotal	V	27	-	-	-	-
WMove	V	21	-	-	-	-
WObs	V	21	-	-	-	-
Height	V	12	-	-	-	-
Restoration	VI	89	2.14	1/26	1.50	0.058
Restoration	VI	89	-	-	-	-

TABLE D.3 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION III[12]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	312	-	7.5/40	10.4	0.26
Conflict	O	81	3.10, 3.17, 3.21, 3.32	-	-	-
max	O	5	-	-	-	-
min	O	4	-	-	-	-
Cieling	O	9	-	-	-	-
Change	O	6	-	-	-	-
Output	O	64	-	-	-	-
DataUpdate	O	75	3.15	-	-	-
Perform Passive Functions	O	5	-	-	-	-
InitVals	O	63	3.5, 3.24, 3.26	-	-	-
Movement	I	94	-	2/40	3.13	0.078
BatPosition	I	67	3.25, 3.6	-	-	-
positioning	I	8	-	-	-	-
Move	I	19	-	-	-	-

12 The fault rate is 40/1200 = 0.00333 faults per line (including data declarations in the line count)

TABLE D.3 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION III

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Observation	II	147	3.34	3/40	4.9	0.123
SubAngle	II	63	3.13	-	-	-
sighting	II	66	3.43	-	-	-
Summation	II	13	-	-	-	-
observe	II	5	-	-	-	-
Attrition	III	131	3.7, 3.8	7/40	4.37	0.109
DoDamage	III	9	-	-	-	-
Weapon Sighting	III	57	3.9, 3.18, 3.19, 3.44, 3.45	-	-	-
Attrition	III	40	-	-	-	-
Aggression	III	19	-	-	-	-
DoAction	III	6	-	-	-	-
Communica tion	IV	407	3.36, 3.37, 3.38, 3.39, 3.40, 3.41, 3.42, 3.35	13.5/40	13.57	0.339
InitRec	IV	14	-	-	-	-
ScanQueue	IV	26	-	-	-	-
PutInQueue	IV	16	3.2	-	-	-
Follow Command Messages	IV	132	3.3, 3.4 3.15	-	-	-
ScanQueue	IV	22	-	-	-	-

TABLE D.3 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION III

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Receive Messages	IV	58	3.23	-	-	-
NM	IV	19	3.1	-	-	-
Compare Recd Messages	IV	46	-	-	-	-
Send Observations	IV	31	-	-	-	-
Send Orders	IV	28	-	-	-	-
Send Messages	IV	5	-	-	-	-
Update	IV	10	-	-	-	-
Environment	V	85	-	5/40	2.833	0.071
Distance	V	4	-	-	-	-
findA	V	16	3.11, 3.20, 3.28, 3.16	-	-	-
Altitude	V	6	-	-	-	-
BI	V	15	-	-	-	-
TM	V	12	3.12	-	-	-
WF	V	14	-	-	-	-
WM	V	10	-	-	-	-
WO	V	8	-	-	-	-
Restoration	VI	24	3.33	2/40	0.800	0.020
Restore	IV	24	3.22	-	-	-

TABLE D.4 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION IV[13]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	271	-	0/23	3.124	0.136
Conflict	O	128	-	-	-	-
Initialize	O	88	-	-	-	-
Prep Output	O	55	-	-	-	-
Movement	I	209	-	0/23	2.410	0.105
Movement	I	38	-	-	-	-
CalcVelocity	I	23	-	-	-	-
MTerrain	I	28	-	-	-	-
Position Squads	I	120	-	-	-	-
Observation	II	266	-	11.5/23	3.067	0.133
Observation	II	49	4.6, 4.7, 4.10, 4.12, 4.18	-	-	-
Init Visual	II	16	4.5	-	-	-
ValidObservation	II	13	4.20	-	-	-
Angle	II	64	-	-	-	-
Line	II	24	4.9, 4.20,4.22	-	-	-
Obs Contrast	II	25	-	-	-	-
Location List	II	20	4.9	-	-	-
Visual Contrast	II	30	-	-	-	-

13 The fault rate is 23/1995=0.01153 faults per line (including data declarations in the line count)

TABLE D.4 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION IV

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
ObsJamming	II	25	4.44.16, 4.20	-	-	-
Attrition	III	318	-	2.5/23	3.67	0.159
Attrition	III	3	-	-	-	-
Inflict	III	12	-	-	-	-
SetCoordinates	III	55	4.8, 4.19	-	-	-
Weapon Count	III	21	-	-	-	-
Weapon Inflict	III	90	-	-	-	-
Suffer	III	13	-	-	-	-
Init Fire List	III	60	-	-	-	-
Squad Damage	III	30	4.3	-	-	-
Is Destroyed	III	4	-	-	-	-
Is Casualty	III	30	-	-	-	-
Communications	IV	584	-	7/23	6.733	0.292
Communications	IV	91	-	-	-	-
Process Msg	IV	65	4.13, 4.14, 4.26	-	-	-
SendMsg	IV	54	-	-	-	-
QueueMsg	IV	90	4.1	-	-	-
ReceiveMsg	IV	81	-	-	-	-
AddToList	IV	50	4.15	-	-	-
CmdReplace	IV	74	4.11, 4.24	-	-	-

TABLE D.4 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION IV

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Report Messages	IV	45	-	-	-	-
Command Messages	IV	34	-	-	-	-
Environment	V	144	-	1/23	1.66	0.072
Altitude	V	23	4.2	-	-	-
Distance	V	39	-	-	-	-
WE Observation	V	22	-	-	-	-
WE Movement	V	21	-	-	-	-
Slope Intensity	V	17	-	-	-	-
Alt Intensity	V	22	-	-	-	-
Restoration	VI	203	-	1/23	2.340	0.102
Restoration	VI	36	-	-	-	-
New Casualties	VI	14	-	-	-	-
Total Casualties	VI	11	-	-	-	-
Restore Amount	VI	25	-	-	-	-
Restore Supplies	VI	18	-	-	-	-
SquadFixers	VI	8	-	-	-	-
Battalion Size	VI	19	4.21	-	-	-
Transfer	VI	72	-	-	-	-

TABLE D.5 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION V[14]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	**362**	-	13/40	9.378	0.234
Conflict	O	81	-	-	-	-
Simulate	O	31	-	-	-	-
Validate	O	149	5.6, 5.7, 5.9, 5.10, 5.11, 5.12, 5.28, 5.30, 5.32	-	-	-
Set Initial Values	O	45	5.3, 5.14, 5.31	-	-	-
Output Results	O	56	5.42	-	-	-
Movement	I	**102**	-	0/40	2.642	0.066
Position	I	58	-	-	-	-
Movement	I	44	-	-	-	-
Observation	II	**305**	5.20, 5.43, 5.37	6/40	7.902	0.198
Observation	II	237	-	-	-	-
SpacePoints	II	50	5.1, 5.17	-	-	-
IntnstyLoc	II	18	5.13, 5.41	-	-	-
Attrition	III	**280**	-	2/40	7.254	0.181
Change Old	III	10	-	-	-	-
Change Squad	III	9	-	-	-	-
Attrition	III	11	-	-	-	-
Suffer	III	60	-	-	-	-

[14] The fault rate is 40/1544 =0.026 faults per line (including data declarations in the line count)

TABLE D.5 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION V

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Inflict	III	152	5.15, 5.16	-	-	-
Wear	III	38	-	-	-	-
Com munication	IV	349	5.2, 5.19, 5.24,5.25,5.26, 5.27,5.39, 5.40 5.21,5.22,5.23	15.5/40	9.041	0.226
Comnicat	IV	239	5.4, 5.5, 5.8, 5.33, 5.34	-	-	-
StoreMess	IV	39	-	-	-	-
ReprtMess	IV	25	-	-	-	-
Commnd Mess	IV	27	-	-	-	-
Update CommVars	IV	19	-	-	-	-
Environment	V	88	-	1.5/40	2.280	0.057
Distance	V	7	-	-	-	-
Altitude	V	19	5.13, 5.41	-	-	-
CompWeath	V	23	-	-	-	-
WEffMov	V	12	-	-	-	-
TEffMov	V	19	-	-	-	-
WEffObs	V	8	-	-	-	-
Restoration	VI	59	5.18	2/40	1.528	0.038
Restoration	VI	59	5.35	-	-	-

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI[15]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequen cy
Others	O	409		4.5/20	3.686	0.184
Conflict	O	95	6.2	-	-	-
Min	O	9	-	-	-	-
Max	O	9	-	-	-	-
IMin	O	9	-	-	-	-
IMax	O	9	-	-	-	-
Ceiling	O	14	-	-	-	-
CheckBatt Constants	O	47	-	-	-	-
Init Battalion	O	88	6.8, 6.20	-	-	-
Initialize	O	44	-	-	-	-
Perfom Simulation	O	24	6.2, 6.4	-	-	-
Perfom OneDt	O	12	-	-	-	-
Prepare For NextDt	O	12	6.7	-	-	-
Determine Output	O	37	-	-	-	-

15 The fault rate is 20/2219=0.0090 faults per line (including data declarations in the line count)

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Movement	I	96	-	0/20	0.865	0.043
Update Battalion Velocity	I	21	-	-	-	-
AlignSquads	I	49	-	-	-	-
Movement	I	9	-	-	-	-
Move Battalion	I	17	-	-	-	-
Observation	II	323	-	3/20	2.911	0.146
Create LOSList	II	11	-	-	-	-
Observation	II	12	-	-	-	-
GenObsList	II	42	-	-	-	-
Observable	II	16	6.1	-	-	-
AngleSub Greater	II	79	-	-	-	-
Updat LOSList	II	13	6.3	-	-	-
LOSClear	II	24	6.16	-	-	-
CntrstOk	II	30	-	-	-	-
Location Intensity	II	30	-	-	-	-
Obs Jamming	II	28	-	-	-	-
SumObs ToNextBatt	IV	38	-	-	-	-

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Attrition	III	201	6.23	5/20	1.812	0.091
Attrition	III	12	6.17	-	-	-
Num Weapons	III	27	6.9	-	-	-
Track Weapons	III	21	6.5	-	-	-
UpdatUse List	III	29	-	-	-	-
Choose Targets	III	45	6.6	-	-	-
Suffer Attrition	III	67	-	-	-	-
Communications	IV	900	6.24	7.5/20	8.112	0.406
Include CommObs	IV	39	6.18	-	-	-
Collect Finished Report	IV	41	-	-	-	-
UpdateLL	IV	42	6.14	-	-	-
Communication	IV	16	-	-	-	-
Send Communications	IV	35	-	-	-	-
Send Report	IV	35	6.2	-	-	-

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
NewNum Send	IV	28	-	-	-	-
Send Command	IV	29	-	-	-	-
ReceiveCom- munications	IV	11	-	-	-	-
Find Receiv- ing Delay	IV	55	6.12	-	-	-
Receive Reports	IV	56	-	-	-	-
Receive Commands	IV	57	-	-	-	-
Update NumVars	IV	30	-	-	-	-
ProcessCom- munications	IV	11	-	-	-	-
Handle Queuing	IV	8	-	-	-	-
Queue Reports	IV	38	-	-	-	-
Find Queue Report	IV	19	-	-	-	-
Queue Commands	IV	38	-	-	-	-
Find Queue Spot	IV	19	-	-	-	-
Processing Delay	IV	24	-	-	-	-

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Process Messages	IV	67	-	-	-	-
Find Next Report	IV	19	-	-	-	-
Find Next Command	IV	20	-	-	-	-
Take A Command	IV	13	-	-	-	-
Take A Report	IV	13	-	-	-	-
New Num Processing	IV	20	-	-	-	-
Collect Commands	IV	42	6.2, 6.11	-	-	-
Collect Command	IV	43	-	-	-	-
PutIn Commands	IV	32	6.13, 6.15	-	-	-
Environment	V	176	-	0/20	1.586	0.079
Distance	V	9	-	-	-	-

TABLE D.6 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VI

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Height	V	28	-	-	-	-
Update Weather	V	7	-	-	-	-
Update Present Events	V	41	-	-	-	-
Add New Events	V	24	-	-	-	-
Weather Severity	V	42	-	-	-	-
WEOn Movement	V	25	-	-	-	-
Restoration	VI	114	-	0/20	1.027	0.051
Restoration	VI	17	-	-	-	-
NewNum Fixers	VI	24	-	-	-	-
Apportion Fixing	VI	53	-	-	-	-
Remove Destroyed Squads	VI	20	-	-	-	-

TABLE D.7 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VII[16] [17]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	603	-	4.5/31	10.385	0.335
Conflict	O	36	7.28	-	-	-
float	O	4	-	-	-	-
WriteError	O	20	-	-	-	-
Process	O	107	-	-	-	
Check Params	O	34	-	-	-	-
Check NAmy	O	13	-	-	-	-
CheckPer Battalion	O	97	7.6, 7.7, 7.8, 7.14	-	-	-
CheckPerSquad	O	21	-	-	-	-
CheckPer Enemy	O	15	-	-	-	-
Check Per Weapon	O	32	-	-	-	-
MakeInt	O	7	-	-	-	-
Initialize	O	54	7.28	-	-	-
SetSuad	O	28	-	-	-	-
UpdateInfo	O	37	-	-	-	-
Update Battalion	O	42	7.28	-	-	-

16 The fault rate is 31/1800=0.0172 faults per line (including data declarations in the line count)

17 In this Version, certain sub procedures are declared in more than one locations

TABLE D7. FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Min	O	6	-	-	-	-
Min	O	5	-	-	-	-
SetOutput	O	24	-	-	-	-
Greatest	O	6	-	-	-	-
Least	O	6	-	-	-	-
CheckBatta lionInfo	O	9	-	-	-	-
Movement	I	**289**	-	0/31	4.977	0.161
Invalid Position	I	10	-	-	-	-
Velocity	I	20	-	-	-	-
SetSquad	I	28	-	-	-	-
Position Squadrons	I	19	-	-	-	-
SetPosition	I	48	-	-	-	-
Velocity	I	20	-	-	-	-
SetPosition	I	48	-	-	-	-
Update Position	I	24	-	-	-	-
Movement	I	19	-	-	-	-
Velocity	I	20	-	-	-	-
Get Difference	I	33	-	-	-	-

TABLE D.7 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Observation	II	**268**	7.17, 7.35	7/31	4.616	0.149
Observation	II	32	7.5, 7.10, 7.13	-	-	-
Visible Squad	II	40	7.1	-	-	-
SubAngle	II	27	-	-	-	-
GetAngle	II	30	-	-	-	-
Series	II	17	7.32	-	-	-
ClearView	II	31	-	-	-	-
OContrast	II	35	-	-	-	-
Intensity	II	18	-	-	-	-
OJamming	II	19	-	-	-	-
Calc Num Observ	II	19	-	-	-	-
Attrition	III	221	-	5/31	3.806	0.123
Initialize WeapData	III	15	7.15	-	-	-
Initialize WeapData	III	15	-	-	-	-
Attrition	III	13	-	-	-	-
Inflict Attrition	III	45	7.2, 7.3, 7.29	-	-	-
SetFire	III	28	-	-	-	-

TABLE D7. FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
CalcNum WeapToUse	III	48	7.27	-	-	-
Calculate Damages	III	31	-	-	-	-
Set Damage	III	9	-	-	-	-
Get Status	III	17	-	-	-	-
Com munication	IV	181	7.18, 7.9, 7.19, 7.20,7.21, 7.22, 7.23, 7.24,7.25	10.5/31	3.117	0.101
Check Messages	IV	21	-	-	-	-
Command Mess	IV	80	7.4	-	-	-
RecDelay	IV	14	-	-	-	-
Jammed Squads	IV	26	-	-	-	-
MakeInt	IV	7	-	-	-	-
Incorporate	IV	33	7.28	-	-	-
Environment	V	141	-	2/31	2.428	0.078
Check Weather	V	19	-	-	-	-
GetTs	V	7	7.11, 7.33	-	-	-
Altitude	V	18	-	-	-	-
Distance	V	8	-	-	-	-
WFactor	V	21	-	-	-	-

TABLE D.7 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
WXPosition	V	5	-	-	-	-
WYPosition	V	5	-	-	-	-
Height	V	10	-	-	-	-
WObserve	V	13	-	-	-	-
W Movement	V	12	-	-	-	-
TerrEffect	V	15	-	-	-	-
Distance	V	8	-	-	-	-
Restoration	VI	97	7.16	2/31	2.0	0.065
DeltaFixSup	VI	13	-	-	-	-
Set Restoration	VI	23	7.12	-	-	-
Change Squad Data	VI	61	-	-	-	-

TABLE D.8 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VIII[18]

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
Others	O	258	-	0/41	7.778	0.190
Conflict	O	93	-	-	-	-
UpdateU	O	14	-	-	-	-
SetKU	O	15	-	-	-	-
Init Variables	O	47	-	-	-	-
Length Of List	O	11	-	-	-	-
UpdateVars	O	53	-	-	-	-
Update Nums	O	4	-	-	-	-
Prepare Output	O	12	-	-	-	-
Ceiling	O	9	-	-	-	-
Movement	I	138	8.18, 8.35	4/41	4.160	0.101
SquadPos	I	54	8.2	-	-	-
Velocity	I	25	-	-	-	-
Movement	I	14	-	-	-	-

18 The fault rate is 41/1366 =0.030 faults per line (including data declarations in the line count)

TABLE D.8 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VIII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
SetLocation	I	45	8.23	-	-	-
Observation	II	203	8.15, 8.19, 8.26	11/41	5.939	0.145
VisContrast	II	7	8.36	-	-	-
Observation	II	60	8.9	-	-	-
Height	II	6	8.41	-	-	-
FindAngle	II	37	-	-	-	-
CalcAngle	II	11	8.37, 8.38	-	-	-
FindPoints	II	17	8.39, 8.40	-	-	-
SumObsJam	II	25	8.14	-	-	-
Observable	II	26	-	-	-	-
ResetObserve Lists	II	14	-	-	-	-
Attrition	III	211	-	3/41	6.361	0.155
Attrition	III	30	8.13	-	-	-
NumOf Weapons	III	15	-	-	-	-
SetAttacked	III	19	-	-	-	-
UpdateK	III	29	8.48	-	-	-
CalcCas	III	21	-	-	-	-
CalcBK	III	22	-	-	-	-

TABLE D.8 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VIII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
UpdateKA	III	23	8.1	-	-	-
UpdateKU	III	21	-	-	-	-
ClearAttack Lists	III	14	-	-	-	-
SetStatus	III	17	-	-	-	-
Communica tion	IV	358	8.27, 8.28, 8.29, 8.30, 8.31, 8.32, 8.33, 8.34	15/41	10.793	0.263
InsertMsg	IV	41	8.5	-	-	-
Command Msg	IV	13	-	-	-	-
InsertCom	IV	17	-	-	-	-
ReportMsg	IV	7	-	-	-	-
InsertRep	IV	29	-	-	-	-
Communica tion	IV	7	-	-	-	-
Receive Delay	IV	31	-	-	-	-
CalRDelay	IV	29	8.12, 8.50	-	-	-
QueDelay	IV	27	-	-	-	-
PutQue	IV	39	8.3, 8.4, 8.6	-	-	-
ProcessQue	IV	28	-	-	-	-
ProcessMsg	IV	39	-	-	-	-
MergeRep Msg	IV	12	-	-	-	-

TABLE D.8 FAULT DISTRIBUTION TO FUNCTIONAL MODULES IN VERSION VIII

Procedure	Type	Lines	Observed Faults	Relative Frequency	Expected Faults	Relative Frequency
MergeCom Msg	IV	39	8.7	-	-	-
Environment	V	110	-	7/41	3.316	0.081
Linear Distance	V	7	-	-	-	-
Altitude	V	19	8.42	-	-	-
WSevFactor	V	20	-	-	-	-
CalcBI	V	24	8.8, 8.10, 8.11, 8.44	-	-	-
Terrain Effect	V	21	-	-	-	-
Weather Move Effect	V	13	8.45	-	-	-
WObsEffect	V	6	8.46	-	-	-
Restoration	VI	88	8.25	1/41	2.653	0.065
UpdateFS	VI	18	-	-	-	-
UpdateFF	VI	15	-	-	-	-
UpdateE	VI	55	-	-	-	-

APPENDIX E: SHARED BOUNDING DIMENSIONS IN FUNCTION-ALLY CLUSTERED FAILURE REGIONS

In this Appendix we present a detailed analysis, whether functional clustering of failure regions results in an increased number of shared[19] bounding dimensions.

The results, are presented in the tables E1 to E8. Each of the tables, corresponds to one of the eight versions of the CONFLICT program (Shimeall 1991, 1991b). Each table entry, corresponds to a pair of failure regions of the same version as in Appendix C.

Table entries on the main diagonal, contain the functional cluster identifier (I, II, III, IV, V, VI, O), for the corresponding failure region (cf. Chapter III). Each of the off diagonal entries contains the Jaccard coefficient for the identical dimensions of the two failure regions labeling the row and column, and the fault type identifier, in case the regions belong to the same functional cluster.

[19] In this analysis, shared dimensions are the ones that correspond to the same predicates, **identical**.

For example, entry (1.1, 1.6) contains 0/O which means that the Jaccard Coefficient for these failure regions is equal to 0, and that both correspond to faults of type O. On the other hand, entry (1.5, 1.12) contains 0.154, so the two failure regions have a Jaccard coefficient equal to 0.154, but correspond to different types of faults (VI and V respectively, in this case).

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.1	1.2	1.3	1.4	1.5	1.6
1.2	0/O	O	-	-	-	-
1.3	0	0	V	-	-	-
1.4	0	0	1.333/V	V	-	-
1.5	0	0.100	0	0	VI	-
1.6	0/O	0/O	0	0	0	O
1.7	0/O	0/O	0	0	0	0/O
1.8	0	0.083	0	0	0	0
1.9	0	0	0	0	0/VI	0/O
1.10	0.333/O	0/O	0	0	0	0
1.11	0.333/O	0/O	0	0	0	0/O
1.12	0	0.0833	0/V	0/V	0.154	0
1.13	0	0	0	0	0	0
1.14	0	0	0	0	0	0

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.7	1.8	1.9	1.10	1.11	1.12	1.13
1.7	O	-	-	-	-	-	-
1.8	0	I	-	-	-	-	-
1.9	0	0.063	VI	-	-	-	-
1.10	0/O	0	0	O	-	-	-
1.11	0 /O	0	0	0.580 /O	O	-	-
1.12	0	0	0	0	0	V	-
1.13	0	0.182	0.083	0	0	0	III
1.14	0	0.067	0	0	0	0	0.143/ III

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.1	1.2	1.3	1.4	1.5	1.6	1.7
1.17	0.333/O	0/O	0	0	0	0/O	0/O
1.18	0	0.100	0/V	0/V	0.083	0	0
1.19	0	0	0	0	0.250	0	0
1.20	0	0.056	0	0	0.053	0	0
1.22	0	0	0	0	0	0	0
1.23	0/O	0/O	0	0	0	0/O	0/O
1.25	0	0	0	0	0.053	0	0
1.26	0	0	0	0	0	0	0
1.27	0	0	0	0	0	0	0
1.28	0	0	0	0	0.500/VI	0	0

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.8	1.9	1.10	1.11	1.12	1.13	1.14
1.17	0	0	0.50/O	0.50/O	0	0	0
1.18	0	0	0	0	0.250\V	0	0.111
1.19	0	0.154	0	0	0.100	0.125	0.067
1.20	0.118	0.048	0	0	0.053	0.133/III	0.105
1.22	0.056	0.600	0	0	0	0.071	0.048
1.23	0	0	0 /O	0/O	0.700	0	0
1.25	0.050	0.045	0	0	0	0.118	0.109
1.26	0	0	0	0	0	0	0/II
1.27	0.120	0.036	0	0	0	0.143/III	0.074 /II
1.28	0	0/VI	0	0	0.143	0	0

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.17	1.18	1.19	1.20
1.17	O	-	-	-
1.18	0	V	-	-
1.19	0	0.100	VI	-
1.20	0	0.100	0.118	III
1.22	0	0	0.067	0.043
1.23	0/O	0.250	0.091	0.050
1.25	0	0	0.059	0.421
1.26	0	0	0	0
1.27	0	0	0.045	0.103
1.28	0	0.071	0.200	0.050

TABLE E.1 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION I

	1.22	1.23	1.25	1.26	1.27	1.28
1.22	IV	-	-	-	-	-
1.23	0	O	-	-	-	-
1.25	0.042/IV	0.048	IV	-	-	-
1.26	0	0	0	II	0	0
1.27	0.033	0	0.061	0/II	II	-
1.28	0	0.357	0.053	0	0	VI

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.1	2.2	2.3	2.4	2.5	2.6
2.1	IV	-	-	-	-	-
2.2	0/IV	IV	-	-	-	-
2.3	0/IV	0.091/IV	IV	-	-	-
2.4	0/IV	0.09/IV	0.300/IV	IV	-	-
2.5	0/IV	0.067/IV	0.133/IV	0.133/IV	IV	-
2.6	0	0.091	0.091	0.083	0.063	V
2.7	0.077	0	0	0	0	0
2.8	0.077	0	0	0	0	0
2.10	0	0	0	0	0	0
2.11	0	0	0	0	0	0
2.12	0	0	0	0	0	0
2.13	0	0.111	0.091	0.091	0.154	0
2.14	0	0	0	0	0	0
2.15	0	0	0	0	0	0

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.7	2.8	2.10	2.11	2.12	2.13	2.14	2.15
2.7	II	-	-	-	-	-	-	-
2.8	0.636/II	II	-	-	-	-	-	-
2.10	0	0	I	-	-	-	-	-
2.11	0	0	0/I	I	-	-	-	-
2.12	0	0/II	0	0	II	-	-	-
2.13	0	0	0/I	0/I	0	I	-	-
2.14	0	0	0	0	0	0	VI	-
2.15	0/II	0/II	0	0	0/II	0.400	0	II

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.1	2.2	2.3	2.4	2.5	2.6
2.16	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.17	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.18	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.19	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.20	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.21	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.22	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.23	0/IV	0/IV	0/IV	0/IV	0/IV	0

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.7	2.8	2.10	2.11	2.12	2.13	2.14	2.15
2.16	0	0	0	0	0	0	0.400	0.400
2.17	0	0	0	0	0	0	0.400	0.400
2.18	0	0	0	0	0	0	0.400	0.400
2.19	0	0	0	0	0	0	0	0
2.20	0	0	0	0	0	0	0	0
2.21	0	0	0	0	0	0	0	0
2.22	0	0	0	0	0	0	0	0
2.23	0	0	0	0	0	0	0	0
2.25	0	0	0	0	0	0	0	0
2.26	0/II	0/II	0	0	0	0	0	0/II
2.30	0	0	0	0	0	0	0	0
2.31	0	0	0	0	0	0	0	0

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.1	2.2	2.3	2.4	2.5	2.6
2.25	0/IV	0/IV	0/IV	0/IV	0/IV	0
2.26	0	0	0	0	0	0
2.30	0	0.111	0.111	0.100	0.071	0.333/V
2.31	0	0	0	0	0	0/V

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.16	2.17	2.18	2.19	2.20
2.16	IV	-	-	-	-
2.17	0.40	IV	-	-	-
2.18	0/IV	0.400/IV	IV	-	-
2.19	0/IV	0/IV	0/IV	IV	-
2.20	0/IV	0/IV	0/IV	0.571/IV	IV
2.21	0/IV	0/IV	0/IV	0.571/IV	0.571/IV
2.22	0/IV	0/IV	0/IV	0.571/IV	0.571/IV
2.23	0/IV	0/IV	0/IV	0.571/IV	0.571/IV
2.25	0/IV	0/IV	0/IV	0/IV	0/IV
2.26	0	0	0	0	0
2.30	0	0	0	0	0
2.31	0	0	0	0	0

TABLE E.2 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION II

	2.21	2.22	2.23	2.24		2.30	
2.21	IV	-	-	-		-	
2.22	0.571 /IV	IV	-	-		-	
2.23	0.571 /IV	0.571 /IV	IV	-		-	
2.25	0 /IV	0 /IV	0/IV	IV		-	
2.26	0	0	0	0	II		
2.30	0	0	0	0	0	V	
2.31	0	0	0	0	0	0/V	V

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10
3.1	IV	-	-	-	-	-	-	-	-	-
3.2	0.60/IV	IV	-	-	-	-	-	-	-	-
3.3	0.25 /IV	0.286 /IV	IV	-	-	-	-	-	-	-
3.4	0 /IV	0/IV	0/IV	IV	-	-	-	-	-	-
3.5	0	0	0	0	O	-	-	-	-	-
3.6	0.143	0.200	0	0	0	I	-	-	-	-
3.7	0.067	0.071	0	0	0	0.07	III	-	-	-
3.8	0	0	0	0	0	0	0/III	III	-	-
3.9	0	0	0	0	0	0	0.48/III	0/III	III	-
3.10	0	0	0	0	0- .17/O	0	0	0	0	O
3.11	0.111	0.125	0.091	0	0	0.13	0.059	0	0	0
3.12	0.111	0.125	0	0	0	0.11	0.188	0	0.087	0
3.13	0	0	0	0	0	0	0	0	0.042	0
3.15	0.077 /IV	0.083 /IV	0.364 /IV	0.100 /IV	0/O	0	0	0	0.040	0/O
3.16	0.11	0.125	0.091	0	0	0.13	0.059	0	0	0
3.17	0	0	0	0	0 /O	0	0	0	0	0/O
3.18	0.067	0.077	0	0	0	0.09	0.714 /III	0/III	0.429 /III	0
3.19	0	0	0	0	0	0	0/III	0/III	0/III	0
3.21	0	0	0	0	0/O	0	0	0	0	0/O
3.22	0.125	0.167	0	0	0	0.20	0.063	0	0.048	0
3.23	0.182 /IV	0.200 /IV	0.077 /IV	0/IV	0.- 0833	0.091	0.111	0	0.040	0.111

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.18	3.19	3.21	3.22	3.23
3.11	V	-	-	-	-	-	-	-	-	-	-
3.12	0.111/V	V	-	-	-	-	-	-	-	-	-
3.13	0	0	II	-	-	-	-	-	-	-	-
3.15	0.067	0	0	O/IV	-	-	-	-	-	-	-
3.16	0.333/V	0.111/V	0	0.067	V	-	-	-	-	-	-
3.17	0	0	0	0/O	0	O	-	-	-	-	-
3.18	0.063	0.059	0	0.056	0.063	0	III	-	-	-	-
3.19	0	0	0	0	0	0	0/III	III			
3.21	0	0	0	0/O	0	0/O	0	0	O	-	-
3.22	0.111	0.100	0	0	0.111	0	0.154	0	0	VI	-
3.23	0.077	0.167	0	0.063/IV	0	0	0.053	0	0	0.833	IV

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10
3.24	0.143	0.167	0.167	0	0.286-/O	0	0.071	0	0	0.2-5/O
3.25	0.125	0.167	0.250	0	0	0.250/I	0.067	0	0	0
3.26	0	0	0.125	0.125	0.571/O	0	0	0	0	0.16-7/O
3.28	0	0.125	0	0.100	0.222	0.125	0.063	0	0	0
3.32	0	0	0.167	0	0/O	0	0	0	0	0/O
3.33	0/IV	0/IV	0.143/IV	0/IV	0	0	0	0	0	0
3.34	0	0	0.143	0	0	0	0	0	0	0
3.35	0/IV	0/IV	0.143/IV	0/IV	0	0	0	0	0	0
3.36	0/IV	0/IV	0.167/IV	0/IV	0	0	0	0	0	0
3.37	0/IV	0/IV	0.143/IV	0/IV	0	0	0	0	0	0
3.38	0.111/IV	0/IV	0/IV	0.125	0.222	0	0.067	0	0	0.167
3.39	0/IV	0/IV	0/IV	0.125	0.222	0	0	0	0	0.200
3.40	0/IV	0/IV	0/IV	0.125	0.222	0	0	0	0	0.200

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.18	3.19	3.21	3.22	3.23
3.24	0	0	0	0.10/O	0	0/O	0.077	0	0/O	0	0.182
3.25	0.111	0.100	0	0.091	0.111	0	0.083	0	0	0.167	0.083
3.26	0	0	0	0.091/O	0	0 /O	0	0	0/O	0	0.083
3.28	0.111 /V	0.11-1/V	0	0	0.111 /V	0	0.063	0	0	0.111	0.083
3.32	0	0	0	0.100/O	0	0 /O	0	0	0.333 /O	0	0
3.33	0	0	0	0.091	0	0	0	0	0.250	0 /VI	0
3.34	0	0	0/II	0.091	0	0	0	0	0.250	0	0
3.35	0	0	0	0.091	0	0	0	0	0.25	0	0

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10
3.41	0.071 /IV	0/IV	0/IV	0.125	0.222	0	0	0	0	0.200
3.42	0/IV	0.111 /IV	0/IV	0.126	0.222	0	0	0	0	0.200
3.43	0.091	0	0	0.167	0	0.143	0.118	0	0.042	0
3.44	0	0.083	0	0	0	0.091	0.770 /III	0/III	0.381 /III	0
3.45	0	0	0	0	0.056	0	0/III	0/III	0.529 /III	0.381

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.11	3.12	3.13	3.15	3.16	3.17	3.19	3.18	3.21	3.22	3.23
3.36	0	0	0	0.091/IV	0	0	0	0	0.250	0	0 /IV
3.37	0	0	0	0.091/IV	0	0	0	0	0.250	0	0 /IV
3.38	0	0	0	0/IV	0	0	0	0.063	0	0	0.08-3/IV
3.39	0	0	0	0/IV	0	0	0	0	0	0	0.08-3/IV
3.40	0	0	0	0/IV	0	0	0	0	0	0	0.08-3/IV
3.41	0	0	0	0/IV	0	0	0	0	0	0	0.08-3/IV
3.42	0	0	0	0/IV	0	0	0	0	0	0	0.08-3/IV
3.43	0.083	0.077	0/II	0	0.083	0	0	0.143	0	0.111	0.067
3.44	0.067	0.063	0	0	0.067	0	0/III	0.910/III	0	0.077	0.056
3.45	0	0.05	0	0	0	0	0/III	0.471/III	0	0	0

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.24	3.25	3.26	3.28	3.32	3.33	3.34	3.35
3.24	O	-	-	-	-	-	-	-
3.25	0	I	-	-	-	-	-	-
3.26	0.333 /O	0	O	-	-	-	-	-
3.28	0.125	0.111	0.333	V	-	-	-	-
3.32	0/O	0	0.167 /O	0	O	-	-	-
3.33	0	0	0.143	0	0.500	VI	-	-
3.34	0	0	0.143	0	0.500	0.400	II	-
3.35	0	0	0.143	0	0.500	0.400	0.400	IV
3.36	0	0	0.143	0	0.500	0.400	0.400	0.40/IV
3.37	0	0	0.143	0	0.500	0.400	0.400	0.40/IV
3.38	0.286	0	0.375	0.200	0	0	0	0/IV
3.39	0.143	0	0.250	0.100	0	0	0	0/IV
3.40	0.143	0	0.250	0.100	0	0	0	0/IV
3.41	0.143	0	0.250	0.100	0	0	0	0/IV
3.42	0.143	0	0.250	0.100	0	0	0	0/IV
3.43	0	0.125	0	0.083	0	0	0 /II	0
3.44	0.077	0.083	0	0.063	0	0	0	0
3.45	0.059	0	0.059	0.053	0	0	0	0

TABLE E.3 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION III

	3.36	3.37	3.38	3.39	3.40	3.41	3.42	3.43	3.44	3.45
3.36	IV	-	-	-	-	-	-	-	-	-
3.37	0.400 /IV	IV	-	-	-	-	-	-	-	-
3.38	0 /IV	0 /IV	IV	-	-	-	-	-	-	-
3.39	0 /IV	0 /IV	0.28-6/IV	IV	-	-	-	-	-	-
3.40	0 /IV	0 /IV	0.286 /IV	0.500 /IV	IV	-	-	-	-	-
3.41	0 /IV	0 /IV	0.286 /IV	0.50-0/IV	0.500 /IV	IV	-	-	-	-
3.42	0 /IV	0 /IV	0.286 /IV	0.500 /IV	0.500 /IV	0.500 /IV	IV	-	-	-
3.43	0	0	0	0.091	0.091	0.091	0.091	II	-	-
3.44	0	0	0.067	0	0	0	0	0.143	III	-
3.45	0	0	0.105	0.053	0.053	0.053	0.053	0.053	0/III	III

TABLE E.4 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION IV

	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12
4.1	IV	-	-	-	-	-	-	-	-	-	-	-
4.2	0	V	-	-	-	-	-	-	-	-	-	-
4.3	0	0.118	III	-	-	-	-	-	-	-	-	-
4.4	0	0	0.045	II	-	-	-	-	-	-	-	-
4.5	0	0	0.063	0.071 /II	II	-	-	-	-	-	-	-
4.6	0	0	0	0/II	0/II	II	-	-	-	-	-	-
4.7	0	0	0.059	0.071 /II	0.16-7/II	0/II	II	-	-	-	-	-
4.8	0	0	0.167 /III	0.059	0.125	0	0.111 /II	III	-	-	-	-
4.9	0	0	0.063	0.07-1/II	0.25-0/II	0/II	0.167 /II	0.125	II	-	-	-
4.10	0	0	0.056	0.06-3/II	0 /II	0/II	0.125 /II	0.091	0.12-5/II	II	-	-
4.11	0 /IV	0.053	0.043	0	0	0	0	0	0	0	IV	-
4.12	0	0	0.063	0.21-4/II	0.16-7/II	0/II	0.12-5/II	0.100	0.167 /II	0.10-0/II	0	II
4.13	0/IV	0	0	0	0	0	0	0	0	0	0	0
4.14	0 /IV	0	0	0	0	0	0	0	0	0	0	0
4.15	0.500	0	0.091	0	0	0	0	0.214	0	0	0	0
4.16	0	0.071	0	0.18-8/II	0 /II	0/II	0 /II	0	0/II	0 /II	0	0.0-8/II
4.18	0	0.100	0	0/II	0/II	0/II	0/II	0	0 /II	0/II	0	0/II
4.19	0	0.100	0/III	0/II	0/II	0/II	0/II	0/III	0/II	0/II	0	0/II
4.20	0	0	0	0/II	0/II	0/II	0/II	0	0/II	0/II	0	0/II

TABLE E.4 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION IV

	4.13	4.14	4.15	4.16	4.18	4.19	4.20	4.21	4.22	4.24	4.26
4.13	IV	-	-	-	-	-	-	-	-	-	-
4.14	0.800 /IV	IV	-	-	-	-	-	-	-	-	-
4.15	0/IV	0/IV	IV	-	-	-	-	-	-	-	-
4.16	0	0	0	II	-	-	-	-	-	-	-
4.18	0	0	0	0.091/II	II	-	-	-	-	-	-
4.19	0	0	0	0.071/II	0.125/II	II/III	-	-	-	-	-
4.20	0	0	0	0/II	0/II	0/II	II				
4.21	0	0	0	0.063	0.083	0.077	0	VI	-	-	-
4.22	0	0	0	0/II	0/II	0/II	0/II	0	II	-	-
4.24	0/IV	0/IV	0/IV	0.083	0.167	0.143	0	0	0	IV	-
4.26	0/IV	0/IV	0/IV	0.071	0.125	0.111	0	0.077	0	0.60 /IV	IV

TABLE E.4 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION IV

	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12
4.21	0	0.071	0	0	0	0	0	0	0	0	0	0
4.22	0	0	0	0/II	0/II	0/II	0/II	0	0/II	0 /II	0	0/II
4.24	0 /IV	0.100	0	0	0	0	0	0	0	0	0/IV	0
4.26	0 /IV	0.083	0	0	0	0	0	0	0	0	0/.IV	0

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9
5.1	II	-	-	-	-	-	-	-	-
5.2	0	IV	-	-	-	-	-	-	-
5.3	0	0	O	-	-	-	-	-	-
5.4	0	0.053/IV	0	IV	-	-	-	-	-
5.5	0	0.059/IV	0	0.375/IV	IV	-	-	-	-
5.6	0	0	0.167 /O	0	0	O	-	-	-
5.7	0	0	0/O	0	0	0/O	O	-	-
5.8	0	0.111/IV	0	0.059/IV	0.067/IV	0	0	IV	-
5.9	0	0.053	0/O	0	0	0/O	0/O	0	O
5.10	0	0	0/O	0	0	0/O	0/O	0	0.143 /O
5.11	0	0	0/O	0	0	0/O	0/O	0	0/O
5.12	0	0	0/O	0	0	0/O	0/O	0	0/O
5.13	0	0.050	0	0.083	0.100	0	0	0.056	0
5.14	0	0	0/O	0	0	0/O	0/O	0	0/O
5.15	0	0	0	0	0	0	0	0	0
5.16	0	0	0	0	0	0	0	0	0
5.17	0/II	0	0	0	0	0	0	0	0
5.18	0	0	0	0	0	0	0	0	0
5.19	0	0/IV	0	0/IV	0/IV	0	0	0/IV	0

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.10	5.11	5.12	5.13	5.14	5.15	5.16	5.17	5.18	5.1 7
5.10	O	-	-	-	-	-	-	-	-	-
5.11	0/O	O	-	-	-	-	-	-	-	-
5.12	0/O	0.20- 0/O	O	-	-	-	-	-	-	-
5.13	0	0	0	V	-	-	-	-	-	-
5.14	0/O	0/O	0/O	0.8	O		-	-	-	-
5.15	0	0	0	0	0	III	-	-	-	-
5.16	0	0	0	0	0	0.71- 4/III	III	-	-	-
5.17	0	0	0	0	0	0	0	II	-	-
5.18	0	0	0	0	0	0	0	0	VI	-
5.19	0	0	0	0	0	0	0	0	0	IV

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
5.20	0/II	0	0	0	0	0	0	0
5.21	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.22	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.23	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.24	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.25	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.26	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.27	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.28	0	0	0/O	0	0	0/O	0/O	0
5.30	0	0	0/O	0	0	0/O	0/O	0
5.31	0	0	0/O	0	0	0/O	0/O	0
5.32	0	0	0/O	0	0	0/O	0/O	0
5.33	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.34	0/II	0/IV	0	0/IV	0/IV	0	0	0/IV
5.35	0	0	0	0	0	0	0	0
5.37	0/II	0	0	0	0	0	0	0
5.39	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.40	0	0/IV	0	0/IV	0/IV	0	0	0/IV
5.41	0/II	0	0	0	0	0	0	0
5.42	0	0	0/O	0	0	0/O	0/O	0
5.43	0/II	0	0	0	0	0	0	0

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.9	5.10	5.11	5.12	5.13	5.14	5.15	5.16	5.17	5.18	5.19
5.20	0	0	0	0	0	0	0	0	0	0	0
5.21	0	0	0	0	0	0	0	0	0	0	0/IV
5.22	0	0	0	0	0	0	0	0	0	0	0/IV
5.23	0	0	0	0	0	0	0	0	0	0	0/IV
5.24	0	0	0	0	0	0	0	0	0	0	0/IV
5.25	0	0	0	0	0	0	0	0	0	0	0/IV
5.26	0	0	0	0	0	0	0	0	0	0	0/IV
5.27	0	0	0	0	0	0	0	0	0	0	0/IV
5.28	0/O	0/O	0/O	0/O	0	0/O	0	0	0	0	0
5.30	0/O	0/O	0/O	0/O	0	0/O	0	0	0	0	0
5.31	0/O	0/O	0/O	0/O	0	0/O	0.130	0.261	0	0	0
5.32	0/O	0/O	0/O	0/O	0	0/O	0	0	0	0	0
5.33	0	0	0	0	0	0	0	0	0	0	0/IV
5.34	0	0	0	0	0	0	0	0	0/II	0	0/IV
5.35	0	0	0	0	0	0	0.040	0.040	0	0/VI	0
5.37	0	0	0	0	0	0	0	0	0/II	0	0
5.39	0	0	0	0	0	0	0.083	0.083	0	0	0/IV
5.40	0	0	0	0	0	0	0	0	0	0	0/IV
5.41	0	0	0	0	0/V	0	0	0	0/II	0	0
5.42	0/O	0/O	0/O	0/O	0	0/O	0	0	0	0	0
5.43	0	0	0	0	0	0	0	0	0/II	0	0

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.19	5.20	5.21	5.22	5.23	5.24	5.25	5.26	5.27
5.20	0	II	-	-	-	-	-	-	-
5.21	0.444/IV	0	IV	-	-	-	-	-	-
5.22	0/IV	0.286	0/IV	IV	-	-	-	-	-
5.23	0.444/IV	0	0.444/IV	0/IV	IV	-	-	-	-
5.24	0/IV	0.286	0/IV	0.286/IV	0/IV	IV	-	-	-
5.25	0.444/IV	0	0.444/IV	0/IV	0.444/IV	0/IV	IV	-	-
5.26	0/IV	0.286	0/IV	0.286/IV	0/IV	0.286/I V	0/IV	IV	-
5.27	0.444/IV	0	0.444/IV	0/IV	0.444/IV	0/IV	0.444/I V	0/IV	IV
5.28	0	0	0	0	0	0	0	0	0
5.30	0	0	0	0	0	0	0	0	0
5.31	0	0	0	0	0	0	0	0	0
5.32	0	0	0	0	0	0	0	0	0
5.33	0/IV	0	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV
5.34	0/IV	0/II	0/IV	0	0/IV	0/IV	0/IV	0/IV	0/IV
5.35	0	0	0	0	0	0	0	0	0
5.37	0	0/II	0	0	0	0	0	0	0
5.39	0/IV	0	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV
5.40	0/IV	0	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV
5.41	0	0/II	0	0	0	0	0	0	0
5.42	0	0	0	0	0	0	0	0	0
5.43	0	0/II	0	0	0	0	0	0	0

TABLE E.5: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION V

	5.28	5.30	5.31	5.32	5.33	5.34	5.3 5	5.3 7	5.3 9	5.4 0	5.4 1	5.4 2
5.28	O	-	-	-	-	-	-	-	-	-	-	-
5.30	0/O	O	-	-	-	-	-	-	-	-	-	-
5.31	0/O	0/O	O	-	-	-	-	-	-	-	-	-
5.32	0/O	0/O	0/O	O	-	-	-	-	-	-	-	-
5.33	0	0	0	0	IV	-	-	-	-	-	-	-
5.34	0	0	0	0	0/IV	IV /II	-	-	-	-	-	-
5.35	0	0	0.053	0	0	0.214	VI	-	-	-	-	-
5.37	0	0	0	0	0	0/II	0	II	-	-	-	-
5.39	0	0	0.125	0	0 /IV	0 /IV	0.063	0	IV	-	-	-
5.40	0	0	0	0	0/IV	0/I V	0	0	0.05- 3/IV	IV	-	-
5.41	0	0	0	0	0	0/II	0	0/II	0	0	II/V	-
5.42	0/O	0/O	0/O	0/O	0	0	0	0	0	0	0	O
5.43	0	0	0		0	0/II	0	0/II	0	0	0/II	0

TABLE E.6 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VI

	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8
6.1	II	-	-	-	-	-	-	-
6.2	0	O/IV	-	-	-	-	-	-
6.3	0.357 /II	0	II	-	-	-	-	-
6.4	0	0/O	0	O	-	-	-	-
6.5	0	0	0	0	III	-	-	-
6.6	0.077	0	0.063	0	0/III	III	-	-
6.7	0.056	0/O	0.048	0/O	0	0.091	O	-
6.8	0.167	0.143/O	0	0/O	0	0.091	0.50/O	O
6.9	0.059	0	0.05	0	0/III	0.1/III	0.286	0.286
6.11	0	0.143/IV	0	0	0	0	0	0
6.12	0	0/IV	0	0	0	0	0	0
6.13	0	0/IV	0	0	0	0	0	0
6.14	0	0/IV	0	0	0	0	0	0
6.15	0	0.111/IV	0	0	0	0	0	0
6.16	0.364/II	0	0.286/II	0	0	0.125	0.083	0.250
6.17	0.056	0	0.048	0	0/III	0.083/III	0.091	0.091
6.18	0	0/IV	0	0	0	0	0	0
6.20	0	0/O	0	0/O	0	0	0/O	0/O
6.23	0.056	0	0.048	0	0/III	0.091/III	0.091	0.091
6.24	0	0/IV	0	0	0	0	0	0

TABLE E.6 : JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VI

	6.9	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18	6.20	6.23	6.24
6.9	III	-	-	-	-	-	-	-	-	-	-	-
6.11	0	IV	-	-	-	-	-	-	-	-	-	-
6.12	0	0/IV	IV	-	-	-	-	-	-	-	-	-
6.13	0	0/IV	0/IV	IV	-	-	-	-	-	-	-	-
6.14	0	0/IV	0.059	0/IV	IV	-	-	-	-	-	-	-
6.15	0	0.143/IV	0.071/IV	0/IV	0/IV	IV	-	-	-	-	-	-
6.16	0.071	0	0	0	0	0	II	-	-	-	-	-
6.17	0.067/III	0	0	0	0	0	0.077	III	-	-	-	-
6.18	0	0/IV	0.067/IV	0/IV	0.40-0/IV	0	0	0	IV	-	-	-
6.20	0	0	0	0	0	0	0	0	0	O	-	-
6.23	0.071/III	0	0	0	0	0	0.077	0.73/III	0	0	III	-
6.24	0	0.071/IV	0.118/IV	0/IV	0.27-8/IV	0.063/IV	0	0	0.467/IV	0	0	IV

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.1	7.2	7.3	7.4	7.5	7.6	7.7
7.1	II	-	-	-	-	-	-
7.2	0.083	III	-	-	-	-	-
7.3	0.083	0.818/III	III	-	-	-	-
7.4	0	0	0	IV	-	-	-
7.5	0.167/II	0	0	0.071	II	-	-
7.6	0	0	0	0	0	O	-
7.7	0	0	0	0	0	0.333/O	O
7.8	0	0	0	0	0	0.333/O	0.500/O
7.9	0	0	0	0.333/IV	0	0	0
7.10	0/II	0.231	0.214	0	0/II	0	0
7.11	0	0	0	0	0	0.200	0.167
7.12	0	0	0	0	0	0	0
7.13	0/II	0	0	0	0/II	0	0
7.14	0	0	0	0.143	0	0/O	0/O
7.15	0.200	0.091/III	0.083/III	0	0	0	0
7.16	0	0	0	0	0	0	0

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.8	7.9	7.10	7.11	7.12	7.13	7.14	7.15	7.16
7.8	O	-	-	-	-	-	-	-	-
7.9	0	IV	-	-	-	-	-	-	-
7.10	0	0	II	-	-	-	-	-	-
7.11	0.167	0	0	V	-	-	-	-	-
7.12	0	0	0	0	VI	-	-	-	-
7.13	0	0	0/II	0	0	II	-	-	-
7.14	0/O	0	0	0	0.100	0	O	-	-
7.15	0	0	0	0	0	0	0	III	-
7.16	0	0	0	0	0/VI	0	0	0	VI

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.1	7.2	7.3	7.4	7.5	7.6
7.17	0/II	0	0	0	0/II	0
7.18	0	0	0	0/IV	0	0
7.19	0	0	0	0/IV	0	0
7.20	0	0	0	0/IV	0	0
7.21	0	0	0	0/IV	0	0
7.22	0	0	0	0/IV	0	0
7.23	0	0	0	0/IV	0	0
7.24	0	0	0	0/IV	0	0
7.25	0	0	0	0/IV	0	0
7.27	0.100	0.200/III	0.273/III	0	0	0
7.28	0	0	0	0/IV	0	0/O
7.29	0.077	0.455/III	0.417/III	0	0	0
7.32	0.048/II	0.038	0.037	0	0/II	0
7.33	0	0	0	0	0	0.143
7.35	0.077/II	0.333	0.400	0	0/II	0

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.7	7.8	7.9	7.10	7.11	7.12	7.13	7.14	7.15	7.16
7.17	0	0	0	0/II	0	0	0/II	0	0	0.400
7.18	0	0	0/IV	0	0	0	0	0	0	0.400
7.19	0	0	0/IV	0	0	0	0	0	0	0.400
7.20	0	0	0/IV	0	0	0	0	0	0	0.400
7.21	0	0	0/IV	0	0	0	0	0	0	0
7.22	0	0	0/IV	0	0	0	0	0	0	0
7.23	0	0	0/IV	0	0	0	0	0	0	0
7.24	0	0	0/IV	0	0	0	0	0	0	0
7.25	0	0	0/IV	0	0	0	0	0	0	0
7.27	0	0	0	0.077	0	0	0	0	0.111/III	0
7.28	0/O	0/O	0/IV	0	0	0	0	0/O	0	0
7.29	0	0	0	0.231	0	0	0	0	0.083	0
7.32	0	0	0	0/II	0	0	0/II	0	0.050	0
7.33	0.125	0.125	0	0	0.333 /V	0	0	0	0	0
7.35	0	0	0	0.20-0/II	0	0	0/II	0	0.091	0

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.17	7.18	7.19	7.20	7.21
7.17	II	-	-	-	-
7.18	0.400	IV	-	-	-
7.19	0.400	0.400/IV	IV	-	-
7.20	0.400	0.400/IV	0.400/IV	IV	-
7.21	0	0/IV	0/IV	0/IV	IV
7.22	0	0/IV	0/IV	0/IV	0.571/IV
7.23	0	0/IV	0/IV	0/IV	0.571/IV
7.24	0	0/IV	0/IV	0/IV	0.571/IV
7.25	0	0/IV	0/IV	0/IV	0.429/IV
7.27	0	0	0	0	0
7.28	0	0/IV	0/IV	0/IV	0/IV
7.29	0	0	0	0	0
7.32	0/II	0	0	0	0
7.33	0	0	0	0	0
7.35	0/II	0	0	0	0

TABLE E.7: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VII

	7.22	7.23	7.24	7.25	7.27	7.28	7.29	7.32	7.33	7.35
7.22	IV	-	-	-	-	-	-	-	-	-
7.23	0.571 /IV	IV	-	-	-	-	-	-	-	-
7.24	0.571 /IV	0.571 /IV	IV	-	-	-	-	-	-	-
7.25	0.429 /IV	0.429 /IV	0.429 /IV	IV	-	-	-	-	-	-
7.27	0	0	0	0	III	-	-	-	-	-
7.28	0/IV	0/IV	0/IV	0/IV	0	O/IV	-	-	-	-
7.29	0	0	0	0	0.182 /III	0	III	-	-	-
7.32	0	0	0	0	0.125	0	0.037	II	-	-
7.33	0	0	0	0	0	0	0	0	V	-
7.35	0	0	0	0	0.200	0	0.333	0.034 /II	0	II

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8
8.1	III	-	-	-	-	-	-	-
8.2	0	I	-	-	-	-	-	-
8.3	0	0.500	IV	-	-	-	-	-
8.4	0	0.143	0.250 /IV	IV	-	-	-	-
8.5	0	1.00	0.500 /IV	0.429 /IV	IV	-	-	-
8.6	0	0.500	0/IV	0.125 /IV	0.500 /IV	IV	-	-
8.7	0	0.333	0.667 /IV	0.111 /IV	0.333 /IV	0.667 /IV	IV	-
8.8	0.250	0	0	0	0	0	0	V
8.9	0	0	0	0	0	0	0	0
8.10	0	0	0	0	0	0	0	0/V
8.11	0	0.333	0.200	0.100	0.250	0.200	0.167	0.667 /V
8.12	0	0	0/IV	0 /IV	0 /IV	0 /IV	0	0
8.13	0.750 /III	0	0	0	0	0	0	0.500
8.14	0.222	0	0	0	0	0	0	0
8.15	0.750	0	0	0	0	0	0	1.00
8.18	0.143	0/I	0	0	0	0	0	0
8.19	0.286	0	0	0	0	0	0	0.500
8.23	0	0.500/I	0.333	0.111	0.333	0.333	0.250	1.00
8.25	0	0	0	0	0	0	0	0
8.26	0	0	0	0	0	0	0	0

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.9	8.10	8.11	8.12	8.13	8.14	8.15	8.18	8.19	8.23	8.25	8.26
8.9	II	-	-	-	-	-	-	-	-	-	-	-
8.10	0	V	-	-	-	-	-	-	-	-	-	-
8.11	0	0/V	V	-	-	-	-	-	-	-	-	-
8.12	0	0	0	IV	-	-	-	-	-	-	-	-
8.13	0.167	0	0	0	III	-	-	-	-	-	-	-
8.14	0.091 /II	0	0	0	0.125	II	-	-	-	-	-	-
8.15	0.20 /II	0	0	0	1.00	0.429 /II	II	-	-	-	-	-
8.18	0	0	0	0	0	0.100	0.250	I	-	-	-	-
8.19	0.125 /II	0.167	0.167	0	0.400	0.2 /II	0.75 /II	0	II	-	-	-
8.23	0	0.50	0.50	0	0	0	0	0 /I	0	I	-	-
8.25	0	0	0	0	0	0	0	0	0	0	VI	-
8.26	0/II	0	0	0	0	0 /II	0 /II	0	0	0	0.667	II

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	8.10
8.27	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.28	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.29	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.30	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.31	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.32	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.33	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.34	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0
8.35	0	0/I	0	0	0	0	0	0	0	0
8.36	0.333	0	0	0	0	0	0	0.143	0.091 /II	0
8.37	0.600	0	0	0	0	0	0	0.333	0.143 /II	0
8.38	0.600	0	0	0	0	0	0	0.333	0.143 /II	0
8.39	0	0	0	0	0	0	0	0	0/II	0
8.40	0.500	0	0	0	0	0	0	0.250	0.125 /II	0
8.41	0.500	0	0	0	0	0	0	0.333	0.143 /II	0
8.42	0	0	0.500	0.143	1.00	0.500	0.333	0/V	0	0/V
8.44	0.333	0	0	0	0	0	0	0.167 /V	0.100	0/V
8.45	0.200	1.00	0.333	0.125	0.500	0.333	0.250	0/V	0	0/V
8.46	0.333	0	0	0	0	0	0.333	0.333 /V	0.200	0/V
8.48	0.5/III	0	0.500	0.143	1.00	0.500	0	0	0	0
8.50	0	0	0/IV	0/IV	0/IV	0/IV	0/IV	0	0	0

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.11	8.12	8.13	8.14	8.15	8.18	8.19	8.23	8.25	8.26
8.27	0	0 /IV	0	0	0	0	0	0	0.500 /IV	0.500
8.28	0	0 /IV	0	0	0	0	0	0	0.667 /IV	0.667
8.29	0	0 /IV	0	0	0	0	0	0	0.400 /IV	0.400
8.30	0	0 /IV	0	0	0	0	0	0	0 /IV	0
8.31	0	0 /IV	0	0	0	0	0	0	0 /IV	0
8.32	0	0 /IV	0	0	0	0	0	0	0 /IV	0
8.33	0	0 /IV	0	0	0	0	0	0	0 /IV	0
8.34	0	0 /IV	0	0	0	0	0	0	0 /IV	0
8.35	0	0	0	0	0	0/I	0	0/I	0	0
8.36	0	0	0.250	0.333 /II	0.571 /II	0.1	0.3 /II	0	0	0/II
8.37	0	0	0.50	0.222 /II	1.0/II	0.167	0.33-3/II	0	0	0/II
8.38	0	0	0.500	0.222 /II	1.00/II	0.167	0.33 /II	0	0	0/II
8.39	0	0	0	0/II	0/II	0	0/II	0/II	0	0/II
8.40	0	0	0.400	0.30-0/II	1.00/II	0.143	0.42-9/II	0	0	0/II
8.41	0	0	0.500	0.333 /II	0/II	0.167	0.50 /II	0	0	0/II
8.42	0.333/V	0	0	0	0	0	0	0.50	0	0
8.44	0/V	0	0.286	0.250	0.667	0.111	0.429	0	0	0
8.45	0.250/V	0	0	0.125	0.500	0.25	0	0.33	0	0
8.46	0/V	0	0.500	0.333	1.00	0	0.500	0	0	0
8.48	0.333	0	0/III	0	0	0	0	0.500	0	0
8.50	0	0/IV	0	0	0	0	0	0	0 /IV	0

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.27	8.28	8.29	8.30	8.31	8.32	8.33
8.27	IV	-	-	-	-	-	-
8.28	0.500 /IV	IV	-	-	-	-	-
8.29	0.333/IV	0.400/IV	IV	-	-	-	-
8.30	0 /IV	0 /IV	0 /IV	IV	-	-	-
8.31	0 /IV	0 /IV	0 /IV	0.444/IV	IV	-	-
8.32	0 /IV	0 /IV	0 /IV	0.667 /IV	0.500 /IV	IV	-
8.33	0 /IV	0 /IV	0 /IV	0.667 /IV	0.500 /IV	0.800/IV	IV
8.34	0 /IV	0 /IV	0/IV	0.364 /IV	0.308/IV	0.400 /IV	0.400 /IV
8.35	0	0	0	0	0	0	0
8.36	0	0	0	0	0	0	0
8.37	0	0	0	0	0	0	0
8.38	0	0	0	0	0	0	0
8.39	0	0	0	0	0	0	0
8.40	0	0	0	0	0	0	0
8.41	0	0	0	0	0	0	0
8.42	0	0	0	0	0	0	0
8.44	0	0	0	0	0	0	0
8.45	0	0	0	0	0	0	0
8.46	0	0	0	0	0	0	0
8.48	0	0	0	0	0	0	0
8.50	0 /IV	0/IV	0/IV	0/IV	0/IV	0/IV	0/IV

TABLE E.8: JACCARD COEFFICIENTS OF FAILURE REGIONS OF VERSION VIII

	8.34	8.35	8.36	8.37	8.38	8.39	8.40	8.41	8.42	8.44	8.45	8.46	8.48	8.50
8.34	IV	-	-	-	-	-	-	-	-	-	-	-	-	-
8.35	0	I	-	-	-	-	-	-	-	-	-	-	-	-
8.36	0	0	II	-	-	-	-	-	-	-	-	-	-	-
8.37	0	0	0.42/II	II	-	-	-	-	-	-	-	-	-	-
8.38	0	0	0.4-3/II	1.0/II	II	-	-	-	-	-	-	-	-	-
8.39	0	0	0/II	0/II	0/II	II	-	-	-	-	-	-	-	-
8.40	0	[illegible]	0.5-0/II	0.75/II	0.750/II	0/II	II	-	-	-	-	-	-	-
8.41	0	0	0.444/II	0.60/II	0.60/II	0/II	0.833/II	II	-	-	-	-	-	-
8.42	0	0	0	0	0	0	0	0/V	V	-	-	-	-	-
8.44	0	0	0.364	0.375	0.375	0	0.444	0.5-0/V	0/V	V	-	-	-	-
8.45	0	0	0.125	0.250	0.250	0	0.200	0.2-5/V	1.0/V	0.1-4-3/V	V	-	-	-
8.46	0	0	0.333	0.400	0.400	0	0.500	0.6-/V	0/V	0.3-75-/V	0.6-67-/V	V	-	-
8.48	0	0	0	0	0	0	0	0	0	0	1.0	0	III	-
8.50	0.083/IV	0	0	0	0	0	0	0	0	0	0	0	0	IV

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